# THE PRESERVATION
OF
# STRUCTURAL TIMBER

Wood Preservation section of the Forest Products Laboratory maintained by the U. S. Forest Service in co-operation with the University of Wisconsin, Madison, Wis. (Forest Service photo.)

*Frontispiece.*

# THE PRESERVATION
OF
# STRUCTURAL TIMBER

BY

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To My

FATHER AND MOTHER

THIS BOOK

IS

AFFECTIONATELY DEDICATED

# PREFACE

The wood-preservation industry is one of those which is aiding in the great movement for efficiency in operation and in the the conservation of our natural resources. Practically unknown in our country but a half century ago, its growth, especially in the last decade, has been exceedingly rapid until there are now nearly 100 plants in operation turning out over 125,000,000 cubic feet of treated wood annually. Too much credit for this splendid development cannot be given to men who like Dr. Hermann von Schrenk have by their ability, knowledge, and persistence brought the importance of preserving wood to the attention of the American people and successfully accomplished a mass of practical results. There is every reason to believe that the growth of the industry has by no means reached its climax, for there are thousands of feet of structural timber used each year that are not being treated but which should and eventually will be.

In an industry which has grown so rapidly and is unique in that a long time must elapse before the efficiency of many of its processes are known, it is but natural that many perplexing problems should arise. The wood preservation industry certainly has its just share of them, and although splendid progress has been made, much yet remains to be learned; in fact, accurate knowledge is just in its infancy. The whole art is permeated with contradictory evidence and opinions so that it is exceedingly difficult for the layman seeking advice to become other than confused.

During the past nine years it has been my good fortune to be thrown in personal contact with many of these problems and to study them over our entire country. While so doing, the need for a book on the subject has been repeatedly called to my attention, for while there are excellent works on given phases of wood preservation, none apparently systematically covers the subject in its broad aspect. It has been necessary to consult a large number of separate publications to secure such data—a process most tedious and unsatisfactory in this day of straight-line operation. Furthermore, it is thought a textbook on timber preserva-

tion will be of help to students in forestry and engineering schools, where a knowledge of wood utilization is desirable and often necessary.

In the following pages, taken largely from lecture notes prepared by the author for the civil engineering students at the University of Wisconsin, it has been the aim to present reliable information of fundamental importance. It is hoped that they will be found of value and use to engineers, foresters, lumbermen, students and all those interested in this subject and that this effort may assist in raising still higher the enviable position already held by the wood-preserving industry.

The author certainly wishes to acknowledge his indebtedness to the U. S. Forest Service, from the publications and illustrations of which he has very heavily drawn; to his friends engaged in commercially treating timber, especially Mr. F. J. Angier, Mr. Carl G. Crawford, and Mr. J. B. Card, whose generous assistance has added much to this book; and to various associations and societies from whose proceedings data have been taken.

H. F. W.

MADISON, WISCONSIN,
*October* 1, 1914.

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## CHAPTER I

## INTRODUCTION

**Definition of Wood Preservation.**—Wood preservation may be defined as the art of protecting structural timber from decay. This is the common acceptance of the term. When considered in its broadest aspect, however, it includes much more than this, since decay is but one factor causing the destruction of wood. It is in its broadest sense that the subject is discussed in this treatise, because it is believed that the practice of protecting from deterioration will broaden as wood increases in value.

In order to adequately treat the subject, wood preservation will be defined as the art of protecting structural timber from deterioration by destructive agents. The more common of these are decay, insects, marine borers, mechanical abrasion, and fire. It should be noted that the definition does not include the protection of trees, as the methods of doing this are entirely distinct from those practised in protecting wood cut from the trees after they have been felled. This distinction should be kept clearly in mind.

**Importance of Wood Preservation as an American Industry.**—In an undeveloped country destined for civilization extensive forests are an obstruction which must be removed, because they occupy land needed for agriculture. As long as a country is heavily timbered, conservative methods of utilizing the timber will rarely be practised. This condition prevailed in the United States during its early history but exists no longer. Scientific methods of managing forests as well as efficient methods of utilizing the timber cut from them, are now being practised. Both, however, are still in their infancy but they are undergoing a rapid application. These economic changes are excellently reflected in the United States in the development of the wood preserving industry.

**Present Standing of the Wood Preserving Industry in the United States.**—There are now about 90 wood preserving plants in active operation in the United States representing a capitalization of over $10,000,000 and turning out products worth about $30,000,000 per year. These plants use annually over 100,000,000 gallons of creosote costing over $7,000,000 and over 21,000,000 pounds of zinc chloride costing about $1,000,000. In addition, about 3,500,000 gallons of various other preservatives are annually consumed representing a value of perhaps $1,250,000. The total amount of wood treated approximates 126,000,000 cubic feet per year, which is equivalent to the amount of wood produced annually by about 10,000,000 acres of average American forest. Since present methods of lumbering waste about 50 percent of the wood grown, the amount of wood now annually treated represents a protection given to the annual output of approximately 20,000,000 acres of timberland.

To the above should be added several millions of dollars spent each year in protecting timber from mechanical destruction and about a quarter of a million protecting wood against fire.

**Conserving our Timber Supply.**—A natural result of the increasing practice of preserving wood is to decrease the drain on our forests and hence help to conserve our supply of timber. This is offset in part by the growth of the country, demanding more raw materials, so that no accurate estimate on the extent to which wood preservation will ultimately decrease the demand for structural timber to be used for replacements can be given. The author attempted such an estimate in 1909 for the National Conservation Commission. Certain modifications now appear advisable, although the estimate as then given has not been materially changed. This revised estimate is given in Table 1. It attempts to show to what extent the demand on our forests can be decreased if all timber placed in situations where it is liable to deterioration were treated in some approved manner. For example, we now use each year about 100,000,000 cross-ties to replace those which have worn out through decay, wear, and other causes. If these ties were given an efficient preservative treatment, their life could be prolonged and in a few years the demand for ties would decrease to about 42,000,000 annually instead of 100,000,000 as at present. Of course this neglects the ever increasing demand for ties due to new construction. Estimating along these lines, it appears that the application of efficient pro-

tective measures to structural timber would decrease the drain on our forests by almost 7,000,000,000 board feet annually, were all such timber which is liable to deterioration protected.

TABLE 1.—ESTIMATED DECREASE IN THE ANNUAL CUT OF TIMBER WHICH WOULD RESULT WERE ALL TIMBER WHICH IS SUBJECT TO DETERIORATION PROPERLY PROTECTED

| Class | Estimated average life in years | | Estimated annual replacements | | Estimated saving in annual cut resulting from proper protection (number) | Total annual saving (M B M) |
|---|---|---|---|---|---|---|
| | Untreated | Treated | Untreated (number) | Treated (number) | | |
| Ties....... | 7 | 17 | 100,000,000 | 41,200,000 | 58,800,000 | 2,000,000 |
| Poles...... | 13 | 26 | 2,500,000 | 1,250,000 | 1,250,000 | 150,000 |
| Posts...... | 8 | 24 | 500,000,000 | 165,000,000 | 335,000,000 | 2,000,000 |
| Piling...... | 3 | 20 | 1,000,000 | 150,000 | 850,000 | 100,000 |
| Mine props. | 3 | 15 | 70,000,000[a] | 14,000,000[a] | 56,000,000[a] | 275,000 |
| Shingles.... | 20 | 35 | 1,000[b] | 600[b] | 400[b] | 400 |
| Lumber.... | 8 | 20 | 3,000,000[b] | 1,200,000[b] | 1,800,000[b] | 1,800,000 |
| Total...... | .......... | .......... | ............ | ............ | ........... | 6,725,000 |

a = cubic feet. b = M B M.

That this shrinkage in the amount of timber cut from forests due to the extended use of preservative treatment is not only a logical but a real outgrowth is shown in part by the experience of France. Although the French forests have been severely culled, they still furnish about 3,000,000 ties annually. Approximately 2,500,000 are used each year for renewals, which number has been steadily diminishing in spite of the fact that the total mileage of the country has been increasing.[1] The practice of preservative treatment in our country has been too recent to make its influence on forest demands as yet apparent but that similar results will be experienced cannot be doubted.

**Effect of Wood Preservation on Forest Management.**—Entirely apart from the problem of husbanding our forest resources is the effect of treating timber on the practice of managing our forests. By giving durability to woods which do not naturally possess it, the practice of wood preservation will in many cases

[1] H. Matheiu, Revue Générale des Chemins de Fer, August, 1887.

govern the manner in which certain forests will be composed and managed.

Forestry teaches that trees grow according to defined onto- and phylogeneric laws, like all other forms of life, and if these laws are violated, destruction will inevitably follow. A layman, for example, may not understand why a young tulip tree will not grow in his dense maple grove.

The utilization of various kinds of timber has shown that some combine more valuable properties for man's purposes than others. A study of these properties has been brought about chiefly through dire necessity. Starting with the cream, man has been forced to the milk. The gums, for instance, classed as "tree weeds" a few years ago, are now eagerly sought and utilized. As a result of these two conditions, namely, the knowledge of the laws of tree growth and the inherent superiority of certain woods for commercial purposes, selected types of forests have been evolved. In other words, man endeavors to eliminate the undesirable species and foster the growth of those best fitted to his needs. The mixed pine and beech forests of Germany may be cited as an illustration. We have not reached this stage in the United States, but with the ever increasing intensity of forest management, nature's combinations will be eradicated, and in their place will be developed man's idea of the Society of the Select. Nature's law which decrees, "Since no two organisms are alike, one must be better adapted to its surroundings than the other, and the less adapted must sooner or later perish," will be changed to read: "Since no two organisms are alike, one must be better adapted to man's needs than the other, and the less adapted must sooner or later perish." This is an illustration from Forest Ecology, which depicts man's disturbing influence in modifying various forms of life to best meet his requirements. Thus the American forest of the future will be radically different in kind as well as in degree from those now existing. Of the forty odd species of commercial trees now found in the Appalachians, it is safe to state that not more than one-fourth will persist. Certain trees, like the hemlock, will become commercially extinct, simply because it will not pay to grow them. This is not a view into the distant future; the careful selection of species is already common practice in Europe, and even now is being actively applied in our country.

As stated, the commercial extinction of certain American

trees and the restriction of others is inevitable, and will be brought about because they lack certain specific qualities. These are of two kinds:

1. Sylvical—the abundance and vitality of the seed; the resistance of the young plants to insects, fire, and animals; their adaptability to their environment; their rate of growth, etc., and

2. Commercial—the size, strength, weight and beauty of the wood, its ease of workmanship, and its durability.

Of all these properties, durability is one of great practical moment and of direct bearing on this treatise. No method is known whereby all kinds of wood can be satisfactorily treated with preservatives. Fortunately, however, the species best adapted to treatment are among the most abundant, and possess certain sylvical and commercial properties which give them a decided advantage over others. These properties briefly are: The vitality and prolificacy of the seed, rapidity of growth, and high percentage of sapwood. The following species may be classed in this group: Bull, lodgepole, loblolly, shortleaf, jack and scrub pines; cottonwood, red and scarlet oaks, silver and red maples; white birch; buckeye; black and cotton gums. All of these, with the possible exception of the bull and shortleaf pines and cottonwood, are commonly classed as "inferior" species. When a timbered area is cut or burned over, these are the commercial species which usually first come in to reforest it. It should be noted that their rate of growth soon culminates. None of them are long lived, and none of them have durable wood. The inherent characteristics of these trees are such as to render a forest composed of them easy to propagate and manage.

Wood preservation thus affects the composition of certain forests as the forests of the future will be grown for specific purposes. White oak will be as rarely used for cross-ties as black walnut now is for fence rails. Future stands of timber will often be composed of those species whose wood without the application of a chemical treatment would have such a limited demand that they could not be grown at a profit.

Suppose that an individual or company has a tract of denuded land upon which it is decided to grow timber. Should slow or rapid growing species be planted? Which will pay better? Almost invariably the wood of the former is more durable than that of the latter, but if figured on the basis of annual financial profit, the advantages are usually in favor of the latter. An

example may be cited: Loblolly pine in an index stand on a 70-year rotation will yield about 33,000 feet B.M. per acre; longleaf pine under similar conditions, on a 120-year rotation, will yield about 25,000 feet B.M. Assuming the value of the land and the cost of planting at $10 per acre, taxes 3 cents, fire protection and management 2 cents per year, and interest 4 percent, the total cost of growing the loblolly at the felling period will be $174 and the longleaf $1244 per acre. The future stumpage price of these species can only be predicted, but at the time the trees were cut, suppose the value to be $8 per thousand feet B.M. for loblolly and $13 for longleaf, or an advance in present prices of over 300 percent for loblolly and 400 percent for longleaf. The value of the crops per acre will then be respectively $264 and $325, or a total profit of $90 for the loblolly and a deficit of $919 for the longleaf. Longleaf, in order to produce a profit equal to the loblolly, would have to be worth about $54 per thousand feet stumpage. At such a price it would be commercially prohibitive. In other words, longleaf pine can be grown only at a loss.

In order to take a most favorable view of a question like the above, let us assume that the land is worth only $1 an acre and that the same yield will be obtained by natural reforestation. Hence, there will be no cost for planting. Moreover, we will assume no charge for protection. The cost of the crops per acre will then be $26.50 for loblolly and $192.90 for longleaf, or net profits respectively of $237 and $132 with an excess of $105 per acre for loblolly pine. Similar examples would be found to exist if other of our slow growing and more durable woods were compared with those listed in the so-called "inferior" group.

Exceptions, of course, occur, notably with such species as black locust, catalpa, osage orange, chestnut, and eucalypts, which combine durability with rapidity of growth. But these trees are of small size or poor form or are subject to insect or fungus attack or are decidedly limited in distribution. Whenever these species can be profitably grown their extension should by all means be encouraged, because they combine many of those qualities in strong demand and their subsequent treatment with preservatives is not a necessity. That the use to which its products will be put often controls the composition of a forest is further shown in this country by the plantations of various railroads. The Pennsylvania, for example, has planted large areas

to so-called "treatment woods," such as red oak in place of the slower growing white oak and other more durable woods mentioned above. The U. S. Forest Service is managing certain of its lodgepole pine forests for the direct purpose of producing cross-ties. Without preservation, it would not pay to use this pine for ties because of its rapid decay. (See Plate I, Fig. A.)

Wood preservation enables trees removed in thinning the forest to be put to a higher use than for fuel and by so doing permits thinnings to be more systematically and effectively made. If a forest plantation is started with 1200 trees to the acre, it is safe to assume that not more than 17 percent—or a total of 204—will remain for the final crop. Those removed will have been cut in the several thinnings when the trees were yet immature, in order to give room for the more thrifty trees. The revenue derived from such thinnings is usually figured on the fuel value of the wood. Such small trees, however, if cut for posts or even poles, and treated, will have their value appreciably augmented, so that thinnings can be made to yield a larger income. Suppose the plantation is loblolly pine and the first thinning is made at 20 years, 600 trees per acre being removed. These will be about 3 inches in diameter and 20 feet high, hence too small to be used advantageously even for fuel. The first thinning will therefore represent a direct apparent loss, which, however, will be recovered by the accelerated growth of the remaining trees. The second thinning will be made at 40 years, and 400 trees will be removed. These will have reached a diameter of 8 inches and a height of 45 feet. If cut for fuel, they would yield about 13 cords worth about $1 per cord stumpage. If cut into posts, however, they would yield about 1600 worth at 2 cents each stumpage a total of $32. Posts of this species, or more generally of inferior species, are worth little unless treated, but when treated their durability may equal or excell that of the more costly varieties, so that it will often prove cheaper to use them. Increased profit derived from thinnings will enable them to be more systematically and carefully made and thus the application of a more intensive system of forest management is made possible. The practicability of a forest working plan depends very largely and in some cases entirely upon direct financial returns, and in any case, if the plan can be made to produce such returns, it will enable forest principles to be more readily applied.

Other things being equal, conservative lumbering pivots upon

the value of the top logs. Change this value and you change the system of marketing. Wood preservation enables the top and inferior logs to be used to better advantage than if left in the woods to rot or sawed into lumber. By raising their value, it intensifies the utilization of timber and fosters its more conservative use. Thus the top logs of such trees as the yellow poplar, black walnut, maple, birch, etc., possess so little value that they are often left in the woods to rot, or when sawed into lumber are frequently sold at a loss. For example, the value of lumber cut from yellow birch logs in the Adirondacks in 1904, 14 inches or less in diameter, was $9.37 per thousand. The cost of stumpage, logging, and manufacturing was at the lowest figure $10.50 per thousand. The operators therefore lost $1.13 per thousand on all such logs removed. For beech the loss amounted to $1.80 per thousand feet B.M. If these logs had been cut into railroad ties, they would, at $5 per thousand stumpage and 15 cents each for logging and manufacture, have cost about 32 cents each and sold for 45 cents each, or a net profit of about $3.90 per thousand feet B.M. Untreated ties of this species have little use on account of their rapid decay. Some lumber companies have already realized the important part wood preservation is playing in their operations and are now manufacturing their logs which are inferior for lumber into ties. An effective system of forest management will recognize this and will change the manner of harvesting the timber so as to get greater returns from it.

Wood preservation accelerates the removal of fire-killed and dead timber and enables areas so denuded to be more speedily reforested and placed upon a profitable basis. Dead timber, whether standing or down, decreases in value each year and land encumbered with it can be likened to capital stock earning no dividend but compelled to pay annuities. There are thousands of acres of just such land in the United States. It is often impracticable to use such dead trees for lumber because of their extensive checks, the stained condition of the wood, or holes bored by insects. Furthermore, on account of rapid decay, the wood may not be usable even for ties, mine props, etc. If treated with preservatives much of this timber can be marketed. Tests made by the author on fire-killed lodgepole pine in Idaho proved it was in ideal condition for preservative treatment. When cut for such purposes its stumpage value in comparison with its former fuel value was raised about 60 percent.

FIG. A.—A stand of young Hodgepole pine in Idaho (Forest Service photo.)

FIG. B.—Egyptian coffin dating from the XII dynasty (2000–1788 B. C.). The only restorations are three cleats on the bottom of the coffin, otherwise it is in almost perfect preservation. (Photo through courtesy of the Metropolitan Museum of Art, New York.)

(Facing page 8.)

PLATE I

FIG. C.—Lentinus lepidens. (Forest Service photo.)

FIG. D.—Lenizites sepiaria. (Photo through courtesy of C. J. Humphrey.)

**History of Wood Preservation.** *Egypt.*—The earliest records of the artificial preservation of organic bodies are found in Egyptian history. The skill shown by the Egyptians in enbalming bodies proves that they carried the art to a high state of perfection. Apparently the wooden coffins in which the bodies were placed were given no special treatment, so that their durability can be accounted for only by the exclusion from the wood of sufficient moisture to allow the growth of wood-destroying organisms. As sycamore was largely used in the construction of these coffins, this furnishes excellent proof of the durability of wood when it can be kept dry; in fact, in such a condition its life is indefinite. (See Plate I, Fig. B.)

Such was not the case, however, in the preservation of the bodies. It is definitely known that these were impregnated with antiseptics, although the exact manner in which this was done is still a matter of conjecture. From the writings of Herodotus it appears that the bodies were first steeped in natrum (a natural substance found in the briny lakes near Cairo and composed principally of sodium sesqui-carbonate, sodium chloride, and sodium sulphate) for about 2 months, after which they were subjected to a bituminous preparation, perhaps by boiling or baking in an oven. Pettigrew extracted the preservatives from the heart of a mummy which had been in a perfect state of preservation for over 3000 years, and the heart at once putrified. Pettigrew's experiments show that the mummies prepared in natrum alone were not as well preserved as those in which solid resins or bitumens were found.

*Europe.*—The quantities of wood used by the early Greeks and Romans in their buildings and bridges caused them to meet squarely the problems of preserving it from decay. Thus among the first attempts were the placing of stone blocks under wooden pillars to keep away soil and vegetation. The tops were also capped in this manner and it is thought that these early practices are the origin of the base and capital of our modern stone pillars. The antiseptic value of essential oils was also well understood, these being obtained from the olive tree and from various cedars and junipers growing along the Mediterranean. The practice was to either rub these oils over the surface of the wood to be preserved, or to bore numerous small holes in the wood and pour oil into them. In this manner the magnificent statue of Jupiter by Phideas and the famous statue of Diana were preserved. Pliny

asserts that the oils not only retarded decay but kept the wood free from insect attacks. It was common practice among the Romans and hut dwellers of the Baltic to char their timbers which were used for piling before placing them permanently in their structures. This method of preserving wood is used even to the present day.

It was perhaps the rapid decay of timber in the British warships that gave wood preservation its first great impetus. It is reported that 40 acres of oak forest were required to construct a 70-gun ship and that the great prevalence of rot in the vessels assumed the proportions of a national calamity.[1] M. Paulet in his book entitled, "Conservation des Bois," enumerates 173 processes or methods that were tried, most of which proved unsuccessful. About this time Holland was also wrestling with the preservation of the timbers used in the construction of her dykes and marine structures. Later came the development of the steam engine and birth of the locomotive, which brought a new drain on the forest, principally for cross-ties, so that some method of preserving wood became a positive necessity. It was during the first quarter of the 19th century that modern methods of injecting wood may be considered as beginning, although the most successful attempts did not come until a few years later. It is interesting to note that the most efficient preservatives were used several years before patents were taken out on them, or even before their use was commercialized. Thus mercuric chloride was used by Homberg in 1705 and by De Boissieu in 1767, although it is with Kyan's name that the salt is best known, he having taken a patent on its use in England in 1832. Even to the present, its use is commonly called "Kyanizing." So it is with copper sulphate, recommended by De Boissieu and Bordenave in 1767 and best known as "Margaryizing," although Margary's patent was not granted until 1837. Chloride of zinc was recommended by Thomas Wade in 1815 and by Boucherie in 1837 but its use is referred to as "Burnettizing" from the patents of Sir William Burnett in 1838. Franz Moll took out a patent in 1836 for injecting wood in closed iron vessels with oils of coal-tar but the practical introduction is attributed to John Bethell, whose patent is dated 1838 and whose name is now famous in the art of preserving timber. It is reported that Bethell's

[1] The Preservation of Timber by the Use of Antiseptics." Samuel B. Boulton, 1885.

process required the timber to be in an air-seasoned condition before the preserving oils were injected. The treatment of green timber with creosote by first using steam followed by a vacuum prior to impregnation with the oil is attributed to Hayford.[1]

The marked success met with by the use of the preservatives mentioned gave a pronounced impetus to the wood-preserving industry throughout Europe. Later, progress was directed more to perfecting the use of these preservatives than in attempting to introduce new ones. Thus it was found that zinc chloride had a tendency to leach from wood, and to overcome this objection as well as give added effectiveness to the treatment, Julius Rütgers introduced in Germany about 1874 a method of treating ties with a mixture of zinc chloride and creosote. This method has met with considerable favor in Germany and is now one of the leading processes in use in that country. The excellent results secured with coal-tar creosote have always caused this preservative to be held in very high repute. Its comparatively high cost led Max Reuping to take out a patent in Germany in 1902 on a process of impregnating it into wood, and subsequently withdrawing a part of it so that the total amount of oil actually consumed was greatly reduced. This process named after the inventor, has also met with pronounced success in European countries. Several other methods of treating wood have lately been exploited in Europe but few of them have met with the success of the Burnettizing and Bethell processes.

Wood preservation is now practised in all the leading European countries. In England creosoting appears most popular, while in Germany both creosote and zinc chloride are extensively used. The same is true of France, where appreciable quantities of poles are still impregnated with copper sulphate. Not only ties and poles but vast quantities of mine timbers, paving blocks, piles, posts, vineyard sticks and lumber are now annually treated, so that the industry may be considered as permanently established and an engineering necessity. Figures on the amount of wood treated in Europe are not available, but it is reported that about 16,000,000 ties are annually preserved and that the total number of plants in operation is about 70. It appears, therefore, that the plants in Europe have on the average a much smaller capacity than those in our country.

*United States.*—The commercial application of wood preserva-

[1] Reprint, Journal of Franklin Institute, 1878.

tion in our country first became of practical importance in 1848, when a Kyanizing plant was built at Lowell, Mass. A great many tests, however, had been carried on in a more or less primitive way previous to this. For example, Kyanized chestnut ties were laid near Baltimore in 1838 by the Northern Central Railroad. The Lowell plant was built primarily for the treatment of timbers used in the locks and canals on the Merrimac River. It operated the Kyanizing process for 2 years, and then substituted the zinc chloride method, but in 1862 the officials, becoming dissatisfied with these treatments, reverted to Kyanizing, and since this date the plant has been in more or less continuous operation.

In 1856, the Vermont Central Railroad erected a Burnettizing plant for the treatment of bridge timbers and ties, but it was abandoned after being in operation 4 years. About this time the Chicago, Rock Island and Pacific, the Boston and Albany and Erie Railroads built plants for the treatment of timber with zinc chloride. All these plants met with but partial success, principally because of the then abundant supply of timber and the high cost and inexperience in handling treated timbers. Operators could not accustom themselves to the delay which timber treatments entailed; consequently few plants treated their timber for a sufficient period to enable it to be properly impregnated with the preservative. In 1863 the Philadelphia, Washington and Baltimore Railroad, and in 1867 the Philadelphia and Reading Railroad built Burnettizing timber-treating plants, but both had a short life due to the unsatisfactory results secured. In 1865, the Old Colony Railroad erected a plant at Somerset, Mass., for the treatment of bridge timbers with creosote. This, apparently, represents the first practical attempt to use this material in the United States. The work was done with a rush and in a careless manner, much of the timber being trimmed after it was treated. In spite of this, the work was considered a success.

In 1867, Professor Seeley of New York obtained a patent for treating timber without the use of pressure. He erected treating plants in New York, Chicago, and at the St. Clair Flats in Michigan. His claim was that green timber could be treated just as effectively as seasoned timber. This, however, accounts in a large measure for Seeley's failure. His process was nevertheless adopted by the Government for its work at the St. Clair Flats in the construction of dikes, etc., along its canal, and by the

Chicago, Rock Island and Pacific and the Chicago, Burlington and Quincy Railroads. At the World's Fair in St. Louis in 1904, von Schrenk revived this "open tank" process, and its use was later on made the subject of careful study by the U. S. Forest Service, until there are now several plants in operation in this country.

About the time Seeley's process was being promoted, Mr. L. S. Robbins introduced a method in which he impregnated timbers with vapors of creosote. This process was extensively advertised and local companies were formed in New York, New Jersey, Pennsylvania, Massachusetts, Connecticut, and California with large capital. It failed, however, in practically all cases, especially where it was used in marine construction. Mr. C. B. Sears, engineer in charge of the government works in California, states "that it failed absolutely to protect the timber from the Teredo, which was not more than 2 months longer in attacking it than the untreated timber, and when once in, its action seemed to be more rapid."

About 1870 Mr. Thilmany treated a great many ties with copper sulphate and barium chloride for the Wabash, Pennsylvania and Ohio, Lake Shore and Michigan Southern, Cleveland and Pittsburg, and Baltimore and Ohio railroads, but the process met with the fate of most of its predecessors and it was eventually abandoned.

In 1872, it is reported, Mr. George H. Fletcher boiled some paving blocks in dead oil of coal-tar and laid them in the yard of the New Orleans Gas Light Company. They absorbed about 20 pounds of oil per cubic foot and when inspected 30 years afterward were thoroughly sound.

Modern timber processes may be considered as beginning in this country in 1875, when a creosote plant was erected at West Pascagoula, Miss., for the treatment of timbers used by the Louisville and Nashville Railroad. This plant is still in operation and has met with marked success in its work. In 1878 Eppinger and Russell operated their creosote plant in Long Island City, N. Y. In 1879 the New Orleans and North Eastern Railroad built a similar plant primarily to treat the timbers used in the bridge across Lake Ponchartrain. From this period on the wood-preserving industry has permanently grown, the Wyckoff Pipe and Creosoting Company erecting a plant in 1881, the Colman Creosoting Company in 1884, the Santa Fe Railway Company in

1885, the Chicago Tie Preserving Company in 1886, etc., until at the present time there are now about 90 plants in operation scattered all over the United States and treating annually over 125,000,000 cu. ft. of wood. (For complete list see Appendix.)

It is interesting to note that the first successful attempts in timber preservation in this country were not made on account of scarcity of timber, but because of the high cost of replacing it after it had deteriorated. For example, the timber-treating plant built by the New Orleans and North Eastern Railroad was erected to treat the timbers used in constructing the Lake Ponchartrain bridge, as these, without treatment, would not last more than 3 or 4 years due to rapid decay and attack by borers. Although treated in 1875, many of these timbers are still sound and in service. Some method of preserving the wood was therefore an absolute necessity to the railroad company in order to maintain this bridge. Similar conditions prevailed in other places along the Atlantic Coast and in mines, but the gradual depletion of our forests and rise in the value of lumber has given a further impetus to the growth of the industry so that there are now but few places in the United States where wood preservation will not pay.

## CHAPTER II

## FACTORS WHICH CAUSE THE DETERIORATION OF STRUCTURAL TIMBER

**Discussion of Their Relative Importance.**—Timber placed in service is subject to deterioration from many causes, and its strength eventually becomes so weakened that it must be removed and replaced with sound timber or some other material. The chief factors which cause such deterioration are decay, insects, marine borers, mechanical abrasion, and fire. Others of less extent are alkaline soils, birds, and sand storms. Our country is so vast and its development has been so rapid, that it is absolutely impossible at this time to even estimate with any degree of accuracy the relative importance of the above factors responsible for the deterioration of structural timbers. In the absence of statistics, it seems very probable, however, that decay is by far the most important, as enormous quantities of wood rot annually. Next in rank to decay, perhaps, comes mechanical destruction, such as the railcutting of ties; then in gradually decreasing amounts, fire, insects, and marine borers. We will discuss in this chapter the manner in which these destructive agents work, as it will aid in understanding the protective measures taken to overcome them.

**Decay.**—On this subject volumes have been written, and it seems strange that even at the present time the cause of decay is a matter little understood by many timber treating engineers.[1] For this reason it is felt desirable to review the more essential facts that are known in the hope that they may clearly fix the basic principles of fungous growth. The prevailing theory about 1840 as to the cause for decay in timber was molded by the opinion of the great chemist Liebig. Liebig taught that the process of fermentation in certain fluids and the putrefying or decay of organized bodies, animal and vegetable, were caused by a species of slow combustion to which he applied the term "eremacausis;" that it required for its ordinary development the pres-

[1] See Proceedings American Wood Preservers' Association, 1912.

ence of moisture and atmospheric air; that its action was provoked by oxygen and its method of action was by a communication of motion by the atoms of the affected ferment to the atoms of the body affected. He denied that fermentation, putrefaction, and decomposition were caused by fungi, parasites or infusoria, although these organisms might sometimes be present during the process.[1]

With the introduction of the microscope and the consequent intensive study on the minute forms of life, the theory of Liebig gradually became shattered. The bodies of mammoths preserved in ice through countless ages, the fragments of wooden piles which have endured undecayed for centuries when driven deeply below the surface of water, all confirm the experiments of Pasteur and Tyndall and prove the exclusion of germs prevents decay. Specimens are on exhibition of a sound wooden pile known as the remains of a bridge (destroyed by fire) which was constructed by Charlemagne across the Rhine; of pieces of piles in the foundation of the bridge across the Medway at Rochester, which was destroyed by Simon de Montfort in 1264. Thousands of exact laboratory tests have established beyond all peradventure, that the true cause of decay in timber are low forms of plants called fungi and bacteria. The action of bacteria in decaying wood is not clearly known even to this day, but there is little reason to doubt but what the same methods used in combating fungi will prove equally as effective in combating them.

Only a comparatively small percentage of fungi and bacteria have the ability to decay wood and a great many will not even grow on wood. Of those which do grow on wood it is customary to divide them, in a discussion of this kind, into "harmful" or wood destroying and "harmless" or saprophytic fungi. All fungi are forms of plants which are parasitic, that is, they are dependent on other plants for their existence. They all lack "chlorophyll," a substance which gives plants their green color and which is instrumental in taking the gases from the air and transforming them into plant substance.

Fungi reproduce in two ways, (1) sexually, by means of minute "spores" which can be likened to tiny seeds, and (2) asexually, by means of "mycelia" which can be likened to minute roots. The spores are blown about by the wind like very fine particles

[1] S. B. Boulton, The Preservation of Timber by the Use of Antiseptics, 1885.

of dust, and when they alight on wood, start to germinate and send their fine mycelia into the wood gradually decaying it. If these mycelia come in contact with sound wood, as for example, when a piece of decayed wood touches a piece of sound wood, they grow into the sound wood and will ultimately decay it. In this way, decay is also spread. Some fungi have the ability to send their mycelia over materials which they will not attack, in their search for wood. Thus if two pieces are separated a foot or more apart, the mycelia from the decayed piece may reach out over this space and attack the sound piece. This characteristic is common in the so-called "house fungus." By the secretion of little understood chemicals by these mycelia, the wood fiber is dissolved and its substance serves as food for the fungus. These chemicals are termed "enzymes" or "ferments." Since fungi vary greatly in their capacity to secrete ferments, we have the key to their widely varying action upon timber. It is only those fungi which attack cellulose and lignin vigorously that effect the durability of timber to any serious degree. Give them a favorable temperature and proper moisture and air supply and the destruction proceeds rapidly.

Fungi may be classified in regard to the form and habit of growth of the "mushrooms" technically called "fruiting bodies." Based on these characters, the "harmful" or wood destroying fungi may be divided into three classes:

1. Fleshy forms of the "mushroom" types which have a distinct stem, a more or less circular cap with plates or "gills" on the under side. This class contains few destructive forms. (See Plate I, Fig. C.)

2. Fungi which are tough, corky or woody and which have no stem, but are attached to the wood by the side of their rough semicircular caps. (See Plate I, Fig. D.) The under surface is provided with pores of various outlines, circular, angular, or sinuous. Frequently the caps grow in clusters, one above the other. This class contains many destructive kinds.

3. Fungi similar to those in class (2), but whose under surface is smooth and not differentiated with pores or plates. (See plate II, Fig. a.)

The "harmless" fungi are comparatively few. There are several species similar to those described in class (1) which grow on wood after it has reached an advanced stage of decay. Another form (Schizophyllum commune) having a wide distribution is

small, white, thin, leathery, and flexible, and has a bracket-like appearance. It frequently occurs on sound oak or pine and lives mostly on the sugars and starches in the wood. Other fungi which are white, green, brown or black and commonly called "molds" also belong to the "harmless" group. They produce the stain in wood but do not injure its strength to any appreciable extent.[1]

**Insects.**—The deterioration of timber through insect attack is greatly underestimated in this country. This matter has been made the subject of a special investigation by the U. S. Bureau of Entomology and it is estimated that the annual loss from this cause amounts to $100,000,000.[2] Round timber with the bark on, such as poles, posts, mine props, saw logs, etc., is particularly subject to attack by round-headed borers, timber worms, and ambrosia beetles. Frequently the insects continue the work in the unseasoned and even dry lumber cut from logs which had been previously infested. Their prolonged activities in mine timbers is well known; also in cabins, and rustic furniture. Hickory hoops and poles are often rendered worthless by borers and beetles. Stave and shingle bolts, handle or wagon stock, and pulpwood are peculiarly subject to attack. Although termites are not usually associated with the destruction of timber in this country, nevertheless they cause considerable damage to poles and construction timbers used in buildings, sometimes completely destroying them. Many of the insects not only feed on the wood but burrow into it for their protection or breeding grounds. This, of course, weakens the wood and allows channels through which water and the spores of destructive fungi can enter. Each specie of insect has its own peculiar method of attack so that it is not possible in a treatise of this kind to describe all of them. Two rather typical examples will, however, be given: The "powder-post insect" which bores into dry wood and the "pole borer" which attacks poles and similar products.

**The Powder-post Insects.**[3]—"The adults or winged forms of this class of insects are small, slender or stout, brownish to nearly black beetles,

[1] For a scientific discussion of the destruction of wood by fungi and bacteria, the reader is referred to Bulletin 266 of the U. S. Bureau of Plant Industry, by McBeth and Scales.

[2] Circular 129, U. S. Bureau of Entomology, A. D. Hopkins, 1910.

[3] Circular 55, U. S. Division of Entomology, by A. D. Hopkins.

FIG. A.—A red-oak tie attacked by a wood destroying fungus (stereum fasciatum, Schw.). (Photo through courtesy of C. J. Humphrey.)

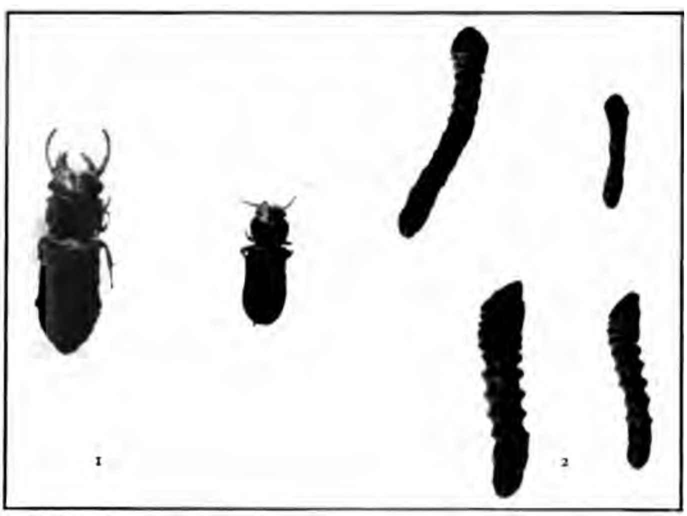


FIG. B.—(1)The pole borer, male and female beetles. (2) Young larvæ. (Circular 134, U. S. Bur. Entomology.)

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PLATE II

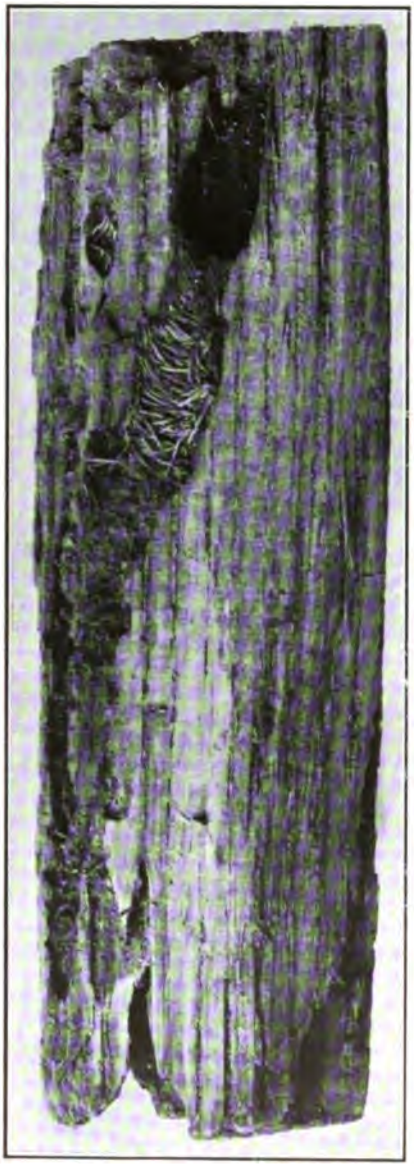

FIG. C.—Gallery of the pole borer.

FIG. D.—Mines of the pole borer near the surface of the ground.

Work of the pole borer (parandra brumiea Fab.) in an untreated chestnut pole. (Circular 134, U. S. Bur. of Entomology.)

which upon emerging from the wood where they breed and pass the winter, fly or crawl about in search of suitable wood material in which to deposit their eggs.

The different species vary in their habits and life history, from the egg to the adult, but in general that of the true powder-post beetles is as follows: The winter is passed in the wood. The eggs are deposited under normal conditions soon after activity commences in the spring, while in storehouses and buildings kept warm and dry they may continue their activity through the year and deposit eggs much earlier. The minute white "worm" or grub (the second stage of the insect known as the larva), upon hatching from the egg, proceeds to burrow in and through the wood in all directions, feeding and growing as it proceeds, until it has attained its full growth. It then excavates a cell at the end of its burrow, in which it transforms to a semidormant stage (the pupa, or third stage in the insect's life), remaining thus until the legs and wings have fully developed, when it bores its way out and appears as the matured adult or beetle (the fourth stage), to mate and repeat the life process. Under normal conditions, so far as is positively known, there is probably only one generation annually.

Each female deposits many eggs, and many females oviposit on or in a single piece of wood, so that the combined work of their numerous progeny, borrowing through the wood in quest of food for their development, results in the complete destruction of the interior wood fiber and its conversion into a mass of fine powder. If the first attack and the first generation do not accomplish this destruction, subsequent generations will follow in the same wood until nothing of the solid fiber is left but a thin outer shell."

**The Pole Borer.**[1]—This insect (Parandra brunnea Fab.), is an elongated, creamy-white, wrinkled, round-headed grub or larva. (See Plate II, Fig. B-2.) It hatches from an egg deposited by an elongate, mahogany-brown, shiny, flattened, winged beetle, from two-fifths to four-fifths of an inch in length. (See Plate II, Fig. B-1.) It appears that the eggs are deposited from August to October in the outer layers of the wood of the pole near the surface of the ground. The young borers, upon hatching, excavate shallow galleries in the sapwood, then enter the heartwood, the mines being gradually enlarged as they develop. As they proceed they closely pack the fine boring dust behind them. This peculiar semidigested boring dust, which is characteristic of their work, is reddish to dunnish yellow in color and has a clay-like consistency. The burrows eventually end in a broad chamber, the entrance to which

[1] Circular 134, U. S. Bureau of Entomology, by T. E. Snyder.

is plugged with excelsior-like fibers of wood. Here is formed the resting stage, or pupa, which transforms to the adult beetle. Often all stages, from very young grubs only about one-fourth inch long to full-grown grubs over 1 inch long, pupæ, and adults in all stages to maturity are present in the same pole. Adults have been found flying from July to September.

The insect attacks poles that are perfectly sound, but will work where the wood is decayed; it will not, however, work in wood that is "sobby" (wet rot), or in very "doty" (punky) wood. It has not yet been determined just how soon the borers enter the poles after they have been set in the ground. However, poles that had been standing only 4 or 5 years contained larvæ and adults of this borer in the heartwood, and poles that had been set in the ground for only 2 years contained young larvæ in the outer layers of the wood.

The presence of the borers in injurious numbers can be determined only by removing the earth from about the base of the pole; the large holes made when the adults come out are found near the line of contact with the soil. Often large, coarse borings of wood fiber project from these exit holes. Sometimes the old dead parent adults are found on the exterior of the poles underground. During August the young adults may be found in shallow depressions on the exterior of poles below the ground surface.

**Marine Borers.**—In many places along both the Atlantic and Pacific coasts timber used for piles in wharfs and other marine structures is attacked by marine wood borers. There are many kinds of such borers but those which occur in our waters can be classed into three genera of mollusks, Xylotrya, Nausitoria, and Teredo, commonly known as "shipworms," and three of crustaceans, Limnoria, Chelura, and Sphæroma, commonly called "wood lice."

The activities of the shipworms were known to the ancient Romans, who sheathed their ships against them. Clement Adams in the reign of Henry VI notes that upon the squadron sent out to discover the Northeast Passage—"they cover a piece of the keels of the shippe with their sheets of leade, for they had heard that in certaine partes of the ocean a kinde of wormes is bredde, which many times pearceth and eateth through the strongest oake that is."[1]

[1] "Voyages and Travels" Vol. II, C. R. Beazley.

**Xylotrya, Nausitoria, and Teredo**[1] in structure and mode of life are very much alike. Hence for all practical purposes a description of the work of Xylotrya will be sufficient (see Fig. 1). The average diameter of an egg is less than 1/500 inch, and a single worm may lay 100 million in a season. When the egg hatches, the embryo swims around for about a month and the exposed surface of the wood is then attacked by countless thousands of them which immediately begin to bore. The hole by which it enters is minute, but beneath the surface the burrow is soon enlarged to accommodate the rapidly growing body. The burrow extends usually in a longitudinal direction and follows a very irregular, tangled course.

There is some controversy as to the method by which boring is accomplished. It is possible that the body is held rigidly by

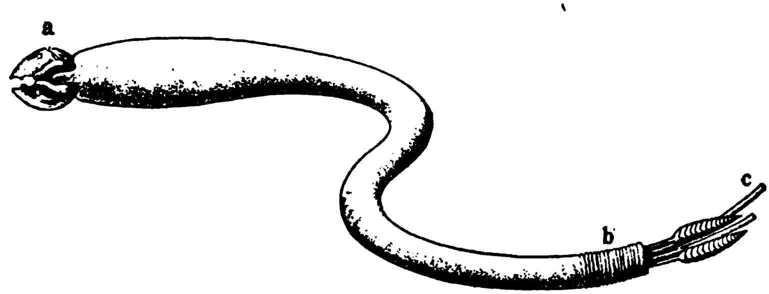


Fig. 1.—Xylotrya or ship worm.

an extensile sucker-like foot, ordinarily incased within the two shell valves (Fig. 1, *a*), and that the two valves revolve around this, cutting the wood away with fine, hard, tooth-like protuberances. It is possible on the other hand that the muscular ring near the posterior end of the body (Fig. 1, *b*) is pressed firmly against the walls of the burrow, and that the whole body, including the shell valves and foot, revolves slightly in both directions, the shell valves doing the cutting. It is probable, however, that the boring is done by a united action of the valves and foot. The posterior muscular end is probably the only portion of the body held rigid. The valves revolve slightly, cutting into the wood, partially in front and partially on the sides. At the same time

[1] Circular 128, U. S. Forest Service, "Preservation of Piling against Marine Borers," by C. S. Smith, 1908.

the foot, either by the secretion of an acid substance, or of spicules used as a grinding medium, assists in breaking down the wood fibers directly in front of the advancing mollusk. The hardest knots are penetrated with ease, but the softer parts of the wood are preferred. As the body grows it secretes a calcareous substance to form a hard lining around the burrow. This is thicker in soft, porous woods than in those which are hard and dense.

At the posterior end of the body, just below the muscular ring, are two siphons, or tubes (Fig. 1, *c*). Through the shorter one the fine borings are ejected with the excreta; through the longer one water and food are taken in. The food consists wholly of infusoria, and is not obtained from the wood itself. The sole object of boring into the wood is to secure a place of shelter.

Xylotrya rapidly attains maturity. High temperatures promote quick work and hasten bodily development. The size attained by the adult depends upon the species, the locality, and the obstacles to excavation. In rare cases a length of 6 feet, with a diameter of over 1 inch, is said to be attained. Other species seldom attain a length of over 5 inches or a diameter of over 1/4 inch.

The portion of the pile commonly attacked is that between mean tide-water mark and a point about 4 feet below low water, though sometimes it extends downward as far as the pressure of the water will permit. The entrance holes do not indicate the extent of attack, as the entrance may be at mean tide-water mark and the active boring head several feet above. On the other hand, part of the excavation may be below the mud line, though the entrance is never so situated. More than half of the weight of the structure may be removed without any visible signs of deterioration upon the surface. When the worm is dead, the minute entrance holes often become filled with mud or débris, so that it is impossible to discover the true condition of the pile without chopping into it.

**The Phola** is primarily a marine stone borer but certain species will attack wood. In form it resembles a long clam. In boring it braces its open shell against the sides of its excavation, while its long sucking foot emerges and rubs the surface of the stone or wood. Particles of sand are operated between the foot and the stone or wood, thus grinding the excavation. Granite, marble, or any kind of stone seems to be attacked. Fortunately, its

ravages on wood are not as extensive as the Xylotrya and Teredo.

Undoubtedly all shipworms thrive best under the influence of heat, though some can endure a relatively low temperature. Certain species have been reported from as far north as Eastport, Me. Since warm water increases their activity and permits them to continue their attacks throughout the greater portion of the year, shipworms are most destructive from Chesapeake Bay south to Florida, on the Gulf of Mexico, and along the entire Pacific coast.

The shipworm may be present in some waters, yet absent in others near by. This is usually due to a difference in the water. Xylotrya appears to be able to endure the brackish water of the inner New York Harbor, while Teredo cannot live there, though it is present in the ocean just outside. The shipworm is very active on the north Pacific Coast, yet it is absent about the mouth of the Columbia River, where the amount of salt in the ocean is influenced by the inflow of fresh water. The effect of water conditions was also noticed in Holland during certain years in which the worms were unusually destructive. Little rain fell during those years, and the small amount of river water brought to the coast was thought to have allowed the ocean to become more saline about the mouths of these streams. Analyses show that there is a variation in the proportion of salt present in the waters of the coast during the dry and the rainy seasons.

Observations along Chesapeake Bay and the Gulf of Mexico indicate the species found there will thrive in waters with a saline density indicated by a specific gravity of from 1.0054 to absolute saturation, 1.0333; that they thrive in temperatures of from 55° F. to the highest found along our coasts; that they work in absolutely clear and in very turbid water; that they seldom work to a depth of over 30 feet; and that the worst attack is usually in the very salty, warm, clear waters.

The length of time required to destroy an average, barked unprotected pine pile in different localities is shown in the following table:

From this table it will be seen that the average life of an untreated pine pile on the Atlantic coast south from Chesapeake Bay and along the entire Pacific coast is but from 1 to 3 years.

| Locality | Length of life reported | |
|---|---|---|
| | Average | Minimum |
| Colon, Panama | 9 months–1 year | |
| Norfolk, Va | 5 years | 1 year |
| Newport News, Va | 2 years | |
| Hampton Roads | 1 1/2 years | |
| St Andrews, Fla | 2–3 years | |
| Pensacola, Fla | 2–3 years | 1 year |
| Fort Morgan, Ala | | 1 year |
| West Pascagoula, Miss | 2–3 years | 1 year |
| Texas City, Tex | 1 year | 29 days |
| Galveston, Tex | 1 1/2 years | 5 months |
| Aransas Pass, Tex | 1 year | 3 months |
| Puget Sound | 1 year | |
| Klawak, Alaska | 3 years | 18–20 months |

Of the crustacean borers, Limnoria, or the "wood louse," is the only one of great importance (Fig. 2). It is gregarious in its habits, and is about the size of a grain of rice. The wood in which it tunnels furnishes both food and shelter. Boring is done with very sharp mandibles. The little galleries excavated are about 1/2 inch long and only slightly larger in diameter than the borer. The galleries extend inward radially, side by side, in countless numbers, so that the wood partitions between them are very thin and are soon destroyed by wave action, thus exposing a fresh wood surface to attack. Boring is carried on at the rate of about 1/2 inch per year. Soft and hard woods are both destroyed, but soft woods much more quickly. If possible, knots, dense summerwood, and other obstructions are avoided. The attack is usually centered upon a limited zone above and below low-water mark. Hence where the tide is great the surface exposed to attack is large.

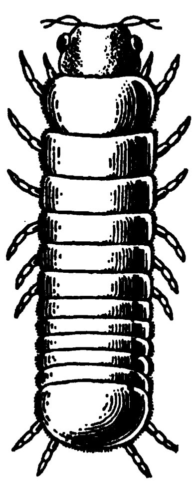

Fig. 2.—Limnoria.

Limnoria is reported by the U. S. Fish Commission as occurring rarely at a depth of 40 feet. It has a wider temperature range than Xylotrya, but requires pure salt water and cannot exist in dirty or fresh water. It is found along the Atlantic coast from Florida to Nova Scotia. It occurs sparingly in Long Island Sound, is quite abundant along the coast of Massachusetts

and in the Bay of Fundy. It also does great damage along the whole Gulf of Mexico, on the north Pacific coast around Puget Sound, and in the Straits of San Juan de Fuca.

All the woods commonly used for piling are subject to the attacks of marine borers. Some doubt has been expressed whether borers attack certain species which are not indigenous to this country and some native woods that have an extremely porous structure. Examples of the first class are certain eucalypts, and of the second class, palms and palmettos. From investigation it is clear that species of the first class are not immune from attack, and that those of the second, although practically immune, are found in such small quantities and are so lacking in the requirements of structural timbers that the fact is not important. Hardness is no barrier to attack, although boring is probably slow in dense woods like ebony, eucalyptus, etc. Whenever partial or complete immunity is reported, it is perhaps largely due to local conditions rather than to the kind of wood.

**Mechanical Abrasion.**—Wood placed in service is often destroyed solely from mechanical causes, and when these cannot be mitigated or eliminated, the protection of such wood from decay is frequently inadvisable. Of the various forms of structural timbers, cross-ties are most subject to serious mechanical wear, and the loss from this cause is estimated at 15 percent of the total number of ties annually destroyed. Wood paving blocks, piling, and planking used in piers, timbers in cars, and all forms of vehicles, mine props, etc., are subject to mechanical deterioration. In many cases no protection can be afforded the timber from such loss, as, for example, occurs in mine props subject to "squeeze." It frequently happens, however, that the wood can be protected by coating its surface with some hard substance such as iron on those portions where the abrasion occurs. At times, protection is afforded by coating the permanent timbers with timbers that are only temporary and whose function it is to absorb shock and stand all wear.

**Fire.**—The action of intense heat on wood is so well understood that little or no comment is necessary. Combustion, of course, occurs, the wood being decomposed into carbon dioxide, water vapor, and ash, so that its original properties are completely changed. Wood which is wet or is in a green condition is much more difficult to ignite than wood which is dry, because it can absorb considerably more heat units in converting the water it

contains into steam. Consequently, wood containing high percentages of water is less liable to injury from fire than wood which is dry. Most structural timbers, however, particularly those used in buildings where they are protected from the weather, are sufficiently dry so that they can easily be ignited. The fire losses in the United States are enormous, reaching a sum estimated at $215,000,000 a year. Of course, the value of the timber actually destroyed is but a small percentage of this amount, most of it being for labor of construction and for other materials and products. There is no doubt but what this loss can be very materially reduced, as is shown by conditions abroad, but to secure most successful results it is felt that the building itself should not only be fire-retardant but that as many of its contents as possible should also be made to resist the flames, and the general public educated to exercise caution.

**Minor Factors.**—In addition to the factors just discussed, there are a number of others of minor importance which destroy or injure wood. The chief of these are alkaline soils, birds, sapstain and sand storms.

**Alkaline Soils.**—In many portions of the United States, particularly in the West, vast areas of soil are more or less alkaline. Generally speaking, two kinds of alkaline soils are recognized, "black" and "white" alkali. Black alkali is sodium carbonate while the white is sodium sulphate and other sodium salts. It has been repeatedly claimed that wood in contact with such soil will be rapidly attacked and soon become worthless. Pieces of wood flumes, poles, and ties have been received that were claimed to have been destroyed by the soil. In all cases examined the specimens showed the presence of wood-destroying fungi. For example: Mr. A. O. Campbell, Assistant Engineer of the Oregon Short Line Railroad Company, submitted for analysis in 1908 several samples of ties, ballast, and soil which he took from a portion of the line known as the Lucin Cutt-off between Ogden and Lucin, Utah. These ties had completely deteriorated in about 8 years. A chemical analysis showed the water-soluble materials washed from the ballast and soil in which the ties were placed contained about 6 percent of sodium carbonate. A microscopic examination of the wood, however, showed it to be full of fungus mycelia. It is thought that the amount of alkali in most alkaline soils is too small to seriously affect the strength of wood in contact with it, but that under certain condi-

FIG. A.—Cedar ties badly damaged by rail cutting. Upper section shows tie without plate, lower section shows tie plate was too small. (Forest Service photo.)

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**Plate III**

Fig. B.—Poles destroyed by a sleet storm in Maryland, 1904. (Forest Service photo.)

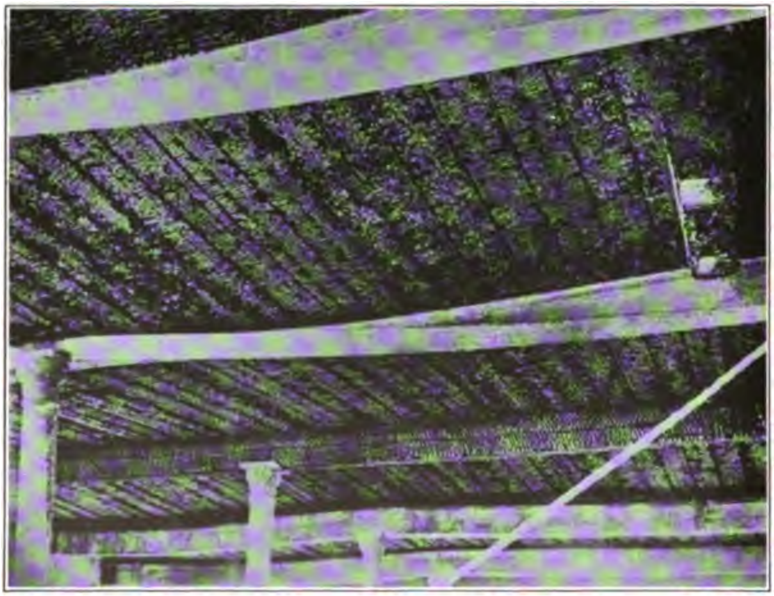

Fig. C.—Results of a fire at the Arlington Manufacturing Company's Mill, Arlington, N. J. In rebuilding, wood beams were used throughout. (Photo courtesy of the Boston Mfg. Mutual Fire Ins. Co.)

tions of warm temperature and abundant moisture, chemical action between the alkali and the wood might occur and deterioration result in time. As the chemical action of these alkalies upon wood even under the most favorable conditions is but slight, as is indicated by tests to reduce wood to pulp, most of the trouble that has been experienced can be attributed to decay.

**Birds.**—Woodpeckers are the only birds which are charged with the destruction of structural timber. Telephone and telegraph poles seem to be the chief forms attacked, although at times they will drill holes into dwellings. In 1906, the author made a count in Louisiana of a number of telegraph poles attacked by woodpeckers.[1] Out of 268 poles, 110 or 41 percent had been bored into. In southern Indiana another examination was made of two pole lines near Greenwood. In one, which extended north, 21 percent of 89 poles examined had been attacked, and in the other, which ran south, out of 58 poles only 59 percent were uninjured.

The woodpeckers which are most injurious are the ant-eating woodpecker (*Melauerpes formicivorous*), the gold-fronted woodpecker (*Centurus aurifrous*), and the red-headed woodpecker (*Melauerpes authrocephalus*), this latter species being the one common in our northern states. The poles are attacked by the birds chiefly for the insects contained in them or for nesting sites. In some cases, however, particularly with the ant-eating woodpecker, they are used as a storehouse for food. These birds will frequently fly for miles with an acorn in their bill, drill a hole in a pole, and insert the acorn in it, to be used later for food.

Woodpeckers usually attack a pole near its top, although at times they may bore within a few feet of the ground. Some observations made on a telegraph line paralleling a railroad in Tennessee showed that those poles which were imbedded in hill tops above the level of the track were the ones most seriously attacked, while those which were in the valleys so that their tops were not higher than the level of the track were seldom attacked. The number of holes in a pole may vary from one to a dozen or more, although these larger numbers are not common. The size of the hole varies from about 1/2 inch to 3 inches in diameter. When used for nesting sites, the birds may

[1] Some observations on the attack of poles by woodpeckers.—H. F. Weiss, Engineering News, January, 1911.

hollow out a pocket 6 or 10 inches in diameter and a foot or more in depth.

The question of interest to telephone engineers is to just what extent such poles are weakened. It has been found from measurements that a 30-foot northern white cedar pole tapers approximately as follows:

| Circumference (inches) | Distance from butt (feet) |
|---|---|
| 43 | 0 |
| 37 | 5 |
| 36 | 6 |
| 34 | 10 |
| 32 | 15 |
| 29 | 20 |
| 27 | 25 |
| 24 | 30 |

Assuming the pole a cantilever beam loaded at one end, it is found that it may be hollowed to the extent shown in Fig. 3 without decreasing its strength. For example, at 10 feet from the ground if only 2 inches of the outer shell are left, the pole will be approximately as strong as though it were solid. If, however, the attack is less than 4 feet from the ground, the pole will be weakened. This illustration neglects the damage done by the entrance into the pole or the subsequent decay which may follow, and assumes that the bird builds its nest exactly in the center. On the other hand, it assumes that the pole has a uniform moisture content throughout its length and that the outer fibers of wood at the ground line are sound.

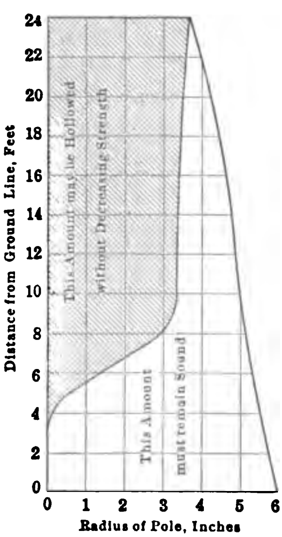


FIG. 3.—Diagram showing the extent to which a pole can be hollowed without impairing its strength.

The American Telephone and Telegraph Company made a few tests in 1908 near Zanesville, Ohio, to determine the effect of woodpecker attacks on the strength of poles. These tests were made by fastening a rope around the top of the pole and pulling with a block and tackle to which a dynamometer was attached. In nine out of

twelve cases the poles broke at the ground line and not at the points attacked by the birds. It appears, therefore, that the destruction of poles by birds is but very slight and, considering the good which they do in destroying insects, is no justification for killing them.

**Sap Stain.**—When freshly cut sap lumber is piled in the open air to season it frequently becomes discolored in a few days. This discoloration is not due to weathering but to the growth of certain fungi which live upon the materials in the sapwood cells. Wood thus attacked is considered defective and its value is frequently reduced from 50 cents to $2 per 1000 feet board measure. Perhaps one-fourth of the annual mill cut of the United States is attacked, the most severe damage being in the South. Any locality where warm damp air surrounds the lumber is favorable to the production of stain. Estimates for the whole country place the annual loss from sap stain at about eight million dollars.

It is commonly held that lumber attacked by stain is decayed and hence reduced in strength. This decay apparently is very slight, because the fungi which produce the stain do not attack the wood substance to any appreciable extent but rather live upon the materials stored in the cells of the wood. Carefully conducted tests on stained and unstained wood were made by the Forest Products Laboratory at Madison, Wis., the results of which are shown in Table 2.

TABLE 2.—SUMMARY OF TESTS SHOWING THE STRENGTH OF SAP-STAINED WOOD[1].

| Species | Moisture per cent at time of test | Condition | Strength in static bending | | | | |
|---|---|---|---|---|---|---|---|
| | | | F.S. at E L. (pounds per square inch) | M. of R. (pounds per square inch) | M. of E. (1000 pounds per square inch) | Res. to M.L. (pounds per cubic inch) | Hardness total load pounds |
| Shortleaf pine... | 17.7 | Unstained | 6,295 | 10,040 | 1,559 | 9.6 | 857 |
| | 9.5 | do | 7,729 | 13,736 | 1,792 | 9.8 | 954 |
| | 8.7 | Stained | 8,902 | 14,081 | 1,883 | 9.4 | 852 |
| Longleaf pine.... | 17.6 | Unstained | 7,322 | 11,679 | 1,785 | 8.5 | 772 |
| | 7.32 | do | 10,932 | 16,759 | 2,187 | 11.97 | 910 |
| | 7.34 | Stained | 11,295 | 17,858 | 2,374 | 11.77 | 883 |

They show that for the same moisture content the heavily stained shortleaf pine was slightly weaker, less tough, and showed less surface hardness than the unstained. In the longleaf pine, which

[1] Circular 192, U. S. Forest Service, "The Prevention of Sap Stain in Lumber," by Howard F. Weiss and Charles T. Barnum.

was only slightly stained, the differences in strength, toughness, and hardness between stained and unstained boards were too slight to be noticed. Immense numbers of minute spores soon form on the freshly cut sapwood and are blown by the wind like dust until they alight on other wood, when they start to germinate. It is chiefly in this way that the stain is spread and because of the enormous numbers of spores produced, lumber cut during the warmer months has little chance of drying without being attacked. So far, then, as this cause is concerned, we may consider sap stain as analogous to decay, but the results as shown above are decidedly different.

## CHAPTER III

## THE EFFECT OF THE STRUCTURE OF WOOD UPON ITS INJECTION WITH PRESERVATIVES

**The Effect of Density upon Absorption.**—It is well known that the structure of wood has a very pronounced effect upon the manner in which preservatives can be injected into it, so that all kinds of wood cannot be handled in the same way and uniform results secured. It is the purpose of this chapter to show the effect of the various structures so far as they are known upon the diffusion of the preservatives, without going into a detailed discussion of wood formation and composition.

For our purposes we may consider wood as being composed of a mass of small, hollow fibers or cells of various sizes and forms more or less closely packed together. The materials of which they are composed are chiefly cellulose and lignin. These substances, in themselves, are heavier than water, so that, were the cells solid, the wood would sink in water. The weight or density of wood is largely dependent upon the amount of air space in the various cells and it is this confined air which gives wood its buoyancy. Thus in woods like ebony or hickory the cells are dense and the air spaces small so that a cubic foot of such wood contains a large percentage of solid wood substance. In other varieties like white pine or cedar the cells have larger air spaces and there is a smaller percentage of solid wood substance so that the wood is light and will readily float in water. Painstaking research has shown that the density of wood substance irrespective of species is practically the same, being about 1.55 specific gravity, or about 97 pounds per cubic foot.

It would appear that woods which are light in weight and hence have considerable air space would absorb preservatives more readily than woods which are heavy. Such, however, is not the case, hence the ability of wood to absorb preservative cannot be judged from its density or weight. In other words, *the resistance of wood to injection with preservatives has little to do*

*with the dry weight of the wood.* This is an important fact on which many writers and engineers have been lead astray. Under identical conditions of test white spruce heartwood which weighed oven-dry 25 pounds per cubic foot absorbed only 6 pounds of creosote per cubic foot, while heart longleaf pine weighing 39 pounds absorbed 13 pounds of the oil. Numerous other examples could be given which prove this beyond all reasonable doubt. There seems, however, to be a rather direct relation between density and absorption in wood of the same species. Thus red oak, for example, which is comparatively light in weight, will absorb more preservative than red oak which is heavy. The difference is not great and has little practical significance. Similar observations have been made on maple.[1] Whether or not the relationship will hold for all species cannot be stated. As the dry weight of certain woods depends on the rate at which the woods have grown, a relationship between absorption and rate of growth can be said to exist, although this is not strongly defined.

**Absorption by the Cell Walls.**—It has been held that the cell walls of wood do not absorb creosote, hence the amount of this oil which can be impregnated into wood depends upon the amount of air space which the wood contains. This claim is not strictly true. Tests made at the Forest Products Laboratory show that the cell walls are capable of absorbing creosote although the amount is very small and of little significance in practical operations.[2] In these tests a number of pieces of hard maple, yew and hemlock, 2 3/4 $\times$ 3/4 $\times$ 1/8 inch were dried in an oven at 212° F. for 24 hours then placed in a desiccator and weighed when cold to the nearest 0.001 gram. The volume of each piece was then determined by displacement and the specimens impregnated with water-free creosote for 1 hour under a pressure of 250 pounds per square inch and temperature of 175° F. The volumes of the pieces after treatment were then determined and compared with the volumes at the same temperatures before treatment.

The average increases in volume resulting from the treatments of the three species in percent of the volumes before treatment were:

[1] Bulletin 126, U. S. Forest Service, "Experiments in the Preservative Treatment of Red Oak and Hard Maple Cross-ties." F. M. Bond, 1913.

[2] Circular 200, U. S. Forest Service, "The Absorption of Creosote by the Cell Walls of Wood," by C. H. Teesdale.

| | Percent |
|---|---|
| Yew, heartwood | 6.81 |
| Yew, sapwood | 10.70 |
| Hemlock, heartwood | 7.30 |
| Hard maple, heartwood | 8.14 |

**The Effect of Sapwood and Heartwood upon Injection.**—The sapwood is commonly defined as that portion of the tree in which the wood cells are alive and perform vital functions. It always occurs immediately under the bark and can usually be distinguished from the heartwood by the lighter color. The width of the sapwood varies considerably in the different kinds of wood, being very narrow in such varieties as chestnut or black locust and wide in others like loblolly pine and red gum. This difference has a very direct bearing on the treatment of wood, because the sapwood of all species can be readily impregnated with preservatives. In some varieties the sapwood is easy to inject while the heartwood is practically impenetrable. This is typified by the red gum and Douglas fir. In other woods like hemlock, there is little difference between the resistance to penetration offered by the sap and heartwood. These differences are often very marked, as is shown in Table 3. The specimens of wood were selected from various species, dried to the same degree of moisture, and all impregnated at the same time in a treating cylinder at the Forest Products Laboratory by the full-cell creosote process.

TABLE 3.—THE ABSORPTION OF COAL-TAR CREOSOTE BY THE HEART-WOOD AND SAPWOOD OF VARIOUS WOODS GIVEN EXACTLY THE SAME TREATMENT. (SIZE OF SPECIMENS 2 × 2 × 12 INCHES; SIX IN EACH TEST)

| Kind of wood | Average absorption of creosote, pounds per cubic foot | |
|---|---|---|
| | Heartwood | Sapwood |
| Douglas fir | 4.38 | 14.46 |
| West. yellow pine | 16.14 | 28.74 |
| Longleaf pine | 12.90 | 34.20 |
| Lodgepole pine | 12.84 | 31.56 |
| Eastern hemlock | 17.28 | 18.78 |
| Alpine fir | 3.66 | 4.14 |
| White spruce | 6.42 | 8.22 |

The reason why sapwood as a rule is more permeable to the passage of preservatives is not definitely known. So far as the size, shape and strength of the cells are concerned there is little difference between those in the sapwood and those in the heartwood. It is quite likely, therefore, that the reason must be looked for in changes which occur in the composition of the cell walls when they are transformed into heartwood cells, or in the cell contents or in the character of the pits in the cell walls which become changed in position and more or less permanently set. Much further work remains to be done before the true cause is determined.

**The Effect of Summerwood and Springwood upon Injection.**—All of the commercially important American woods grow by adding a successive layer of wood with each successive year of life. These layers are concentric and are called "annual rings." Normally, one such annual ring or layer is produced each year, so by counting the number of such rings from the center to the outside of a piece of wood, the number of years it took to grow the wood can be directly determined. In most varieties of trees there is a vast difference between the character of the wood in the annual ring formed in the spring and that formed in the summer. The former is called "springwood," the latter "summerwood." Thus in longleaf pine, for example, the cells in the springwood have much thinner walls than those in the summerwood. This of course makes the springwood much lighter and weaker than the summerwood and causes the banded appearance so noticeable in edge or "comb-grained" yellow pine lumber. In other coniferous woods like white spruce the difference in the cells of the spring and summerwood is not so pronounced and hence such wood is much more uniform. The same differences occur in certain hardwoods like oak, ash, etc., where many of the cells in the springwood are so large as to be called "pores" or "vessels." In other hardwoods like the maple, beech, birch, etc., the difference between the spring and summerwood is slight and hence these woods possess greater uniformity. In all woods which have no marked difference in the spring and summerwood the injection of preservatives is fairly uniform throughout the entire annual ring. The beech, maples, firs, spruces, etc., fall in this class. (See Plate IV, Fig. D.) Great irregularity in penetration and absorption occurs in the other types of wood. Thus in longleaf pine, red oak, ash, etc., the treatment will often appear in bands

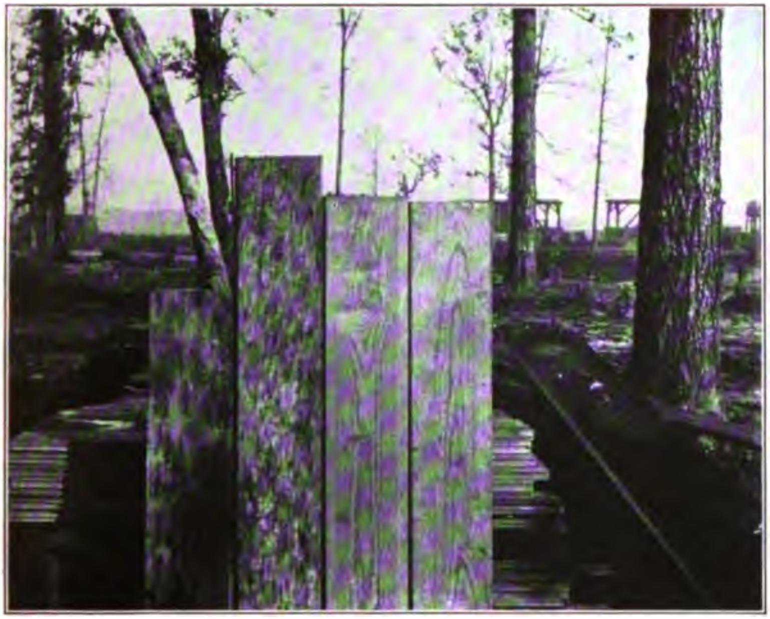

FIG. A.—Longleaf pine boards piled solidly after one month's exposure to sap stain fungi. Boards on left, untreated; boards on right dipped in a weak solution of mercuric chloride. Note absence of stain. (Forest Service photo.)

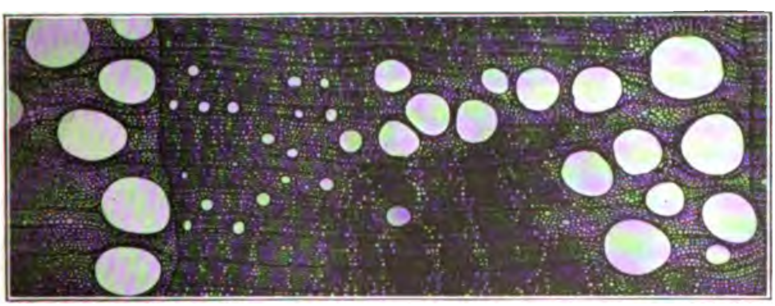

Fig. B.—Cross section through red oak—a "ring porous" wood. Note arrangement of pores mostly in the spring wood. Note also clearness of pores. ×50. (Forest Service photo.)

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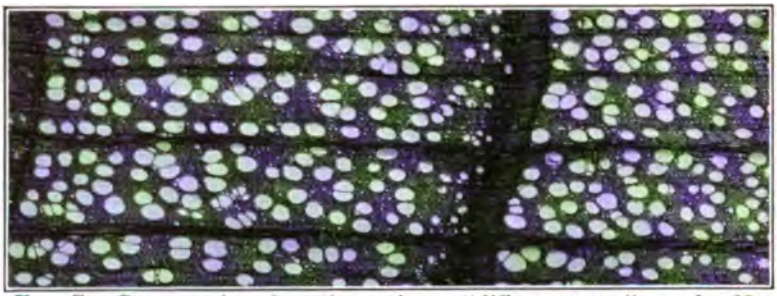

FIG. C.—Cross section through maple—a "diffuse porous" wood. Note pores scattered through entire width of annual ring. ×50. (Forest Service photo.)

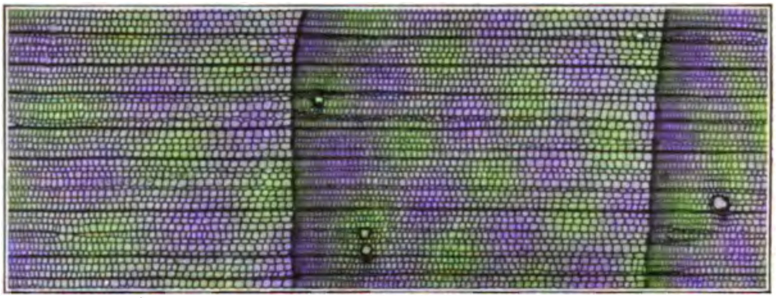

FIG. D.—Cross section through spruce—a "nonporous" wood. Note absence of pores. Larger openings are "resin ducts" or cells. × 50. (Forest Service photo.)

FIG. E.—Cross section through white oak. Note pores clogged with "tyloses." Compare with red oak. × 50. (Forest Service photo.)

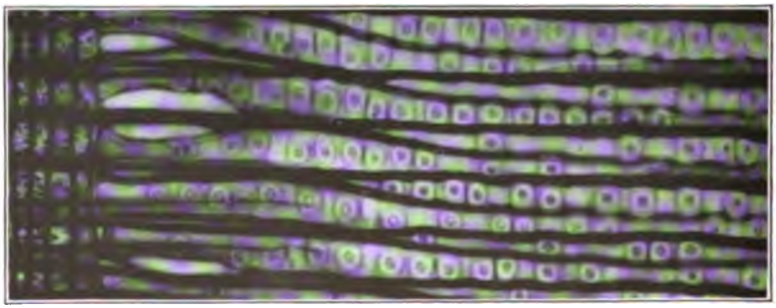

FIG. F.—Radial section through pine. Note bordered pits or "eyes," also how fibers fit into one another. Vertical cells on extreme left are medullary or "pith ray" cells. × 250. (Forest Service photo.)

(in a cross section view) or streaks (in a radial view). This is because the spring and summerwood offer different resistances to the passage of the preservative. In red oak and ash most of the preservative will be found in the springwood, while in longleaf pine most of it occurs in the dense summerwood. The exact reasons why these differences occur will be described further on. It follows, therefore, that the rate at which certain woods grow affects very appreciably the uniformity of the treatment secured. When the tree grows rapidly, the annual rings are comparatively wide, hence the bands of heavy and light treated wood are pronounced. (See Plate V, Fig. A.) When growth has been slow these rings are narrower and the bands are much less pronounced. (See Plate V, Fig. B.) In general, therefore, the species which have pronounced differences in the spring and summerwood have a much greater irregularity in the treatment of the annual rings than those which are of a more uniform stucture, especially when of rapid growth. It is largely because of these differences that the number of rings per inch allowed in certain classes of material, such as paving blocks, is specified.

**The Effect of Vessels or "Pores" on the Treatment of Wood.**—All varieties of American "hardwoods" possess elongated cells called "vessels" or "pores." These are characteristic of hardwoods and form a reliable means of distinguishing such woods from the "conifers" in which the vessels are entirely absent. These pores occur in two ways: first, scattered through the annual rings, and second, as bands of "rings" in the springwood of the annual ring. Because of this difference the hardwoods are commonly classified as diffuse porous (maple, birch, beech, etc.) and ring porous (oak, ash, hickory, etc.). These pores, which are often so long as to resemble capillary tubes, are easily filled with preservative and offer ready channels for conducting the preservative into the wood.[1] Thus in red oak the pores are so long that it is possible to blow through a piece of this wood 4 feet or more in length. It can be easily understood, therefore, why such woods readily absorb preservatives and why the character of the treatment secured depends so much upon the arrangement of the pores.

**The Effect of Tyloses on the Treatment of Wood.**—It frequently happens that the vessels described above are clogged with a cell

[1] When the pores are filled with "tyloses" this statement does not hold. See discussion under "tyloses."

growth which prevents the passage of air or liquids through them. This growth is characteristic of certain kinds of wood like white oak and black locust and renders them practically impervious to absorption. It is caused by cells, called "tyloses," growing into the vessels. (See Plate IV, Fig. E.) These may occur even in the sapwood and when they are present the vessels cannot be penetrated. In some kinds of wood like white oak, tyloses are uniform throughout, only a few vessels being without them. In other varieties, like black oak, tyloses occur irregularly through the wood. Thus in certain parts of a stick the vessels may be few and the preservative will readily enter, while in another part the tyloses may fill the vessels and absolutely prevent any entrance of the preservative. In such cases a very irregular diffusion of the preservative naturally occurs. There is no way of telling to what extent the tyloses occur in these woods except by a careful microscopic examination. From a large number of microscopic examinations of various American woods it is possible to class them into three groups depending upon the presence or absence of tyloses.[1]

Group 1—**Tyloses absent**—the maples, birches, blue beech, flowering dogwood, holly, silverbell, black and water gums, black and red cherry, basswood, persimmon, honey locust.

Group 2—**Tyloses few**—yellow buckeye, beech, red gum (sap), yellow poplar, magnolias, sycamore, black cottonwood, eucalyptus (blue gum), white and Oregon ashes, and the elms.

Group 3—**Tyloses abundant**—large tooth aspen, hardy catalpa, desert willow, green, pumpkin and blue ash, mockernut, water pignut, shellbark, bitternut, nutmeg and shagbark hickories, butternut, black walnut, red mulberry, blackjack, white, Garry, overcup, valley, burr, cow, post and swamp white oaks, black locust, and osage orange.

Tyloses were also found very scatteringly in the pines, but in no other conifers examined.

**The Effect of Resin Ducts on the Treatment of Wood.**—As mentioned above, conifers do not possess vessels or pores. Some of them do, however, have a structure which, so far as a penetration with preservatives is concerned, functions like pores. This structure is called a "resin duct," and as the name implies, it is a duct or "pore" usually producing and containing resin. Except when the ducts are clogged with resin or some other obstruction,

[1] From examinations by Eloise Gerry, U. S. Forest Products Laboratory.

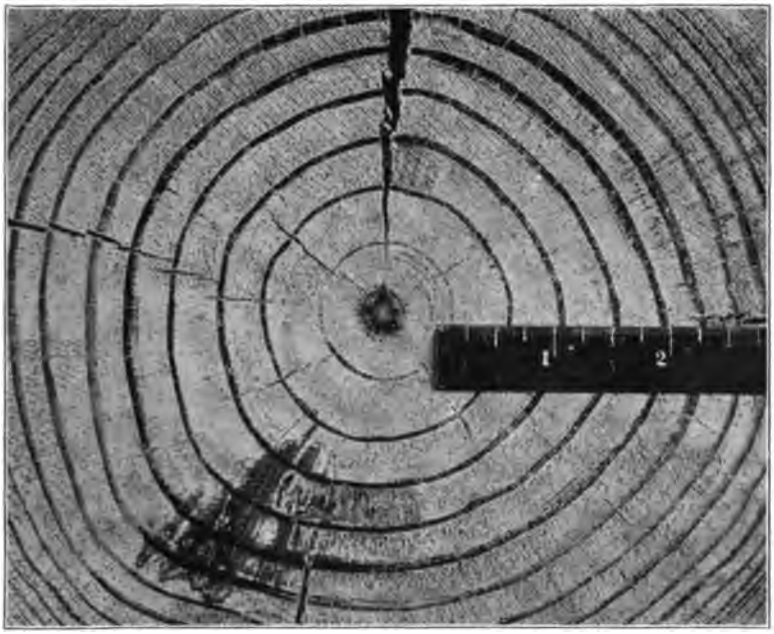


FIG. A.—Cross section through a lolbolly pine tie. Note wide rings showing rapid growth, also note sharp transition of spring wood and summerwood.

FIG. B.—Cross sections through two long leafpine stringers. Note narrow rings especially in sapwood, showing slow growth. (Forest Service photo.)

(Facing page 36.)

FIG. C.—Cross section through the summerwood of larch (greatly magnified) showing slits in cell walls. (Forest Service photo.)

FIG. D.—Showing ease with which chestnut peels in the spring. (Author's photo.)

they afford channels for the ready penetration of the preservative. Some experiments have been made at the U. S. Forest Products Laboratory to determine the effect of resin in the ducts upon the entrance of coal-tar creosote. It was found that such resin, particularly when it is old, has a very marked effect in retarding the entrance of the oil. When the test blocks of wood were first extracted with a resin solvent and then dried, the creosote entered the wood very easily.

The position of the resin ducts in the wood affects very materially the character of the treatment. Thus, in longleaf and loblolly pines the resin ducts are largely in the summerwood and because of this the summerwood is more penetrable than the springwood even though it is much denser. Some exacting tests have been made by C. H. Teesdale to secure definite information on this point. Pieces of the summerwood of loblolly pine which had a specific gravity of 0.95 and pieces of springwood cut from the same specimens which had a specific gravity of 0.39 were impregnated at the same time with coal-tar creosote. The summerwood absorbed 1.8 times as much creosote as the springwood. There is little doubt but what the resin ducts had much to do with this difference and it is largely because of them that longleaf pine paving blocks often show a "banded" treatment. In redwood the ducts occur mostly in the springwood and in this species a better absorption and penetration of preservative is secured in the springwood than in the summerwood.

The resin ducts also occur in certain species in the medullary or pith rays. These are layers of cells which radiate from the circumference of the tree to the center. In all coniferous woods which possess such ducts, good radial penetration of the preservative is secured (from the outside toward the center). This fact is of considerable importance commercially because in order to secure good treatments, especially in round timbers like poles or piles, it is essential to peel all of the bark off them; otherwise the ends of the ducts will be plugged by the bark and little or no penetration at that point secured. It is believed that carelessness in peeling such woods is one cause of the rapid destruction of creosoted piling, as it leaves streaks of untreated wood extending to the interior of the stick and thus affords avenues of attack by marine borers. Pieces of wood $2 \times 4 \times 25$ inches were impregnated by Teesdale with coal-tar creosote under identical conditions. Those which contained radial resin ducts

were penetrated radially from one-fourth to three-fourths as far as they were longitudinally. In those woods which had no radial ducts, the radial penetration varied from one-twentieth to one one-hundred twentieth of the longitudinal penetration. Practically all of the pines belong to the former class, while many of the larches, firs, hemlocks, and spruces belong to the latter.

**The Effect of Pits upon Injection.**—The penetration of preservatives in woods containing vessels and resin ducts can largely be explained by their presence. In certain woods, however, where neither of these are present or where they are restricted, the manner in which penetration occurs is not easy of explanation. According to Bailey,[1] "whenever preservatives are injected rapidly into green or seasoned wood, the penetration takes place primarily through the cavities of the cells, and the preservatives pass from one cell to another through the bordered pits." These bordered pits may be likened to microscopic "valves" occurring in the walls of the cells. (See Plate IV, Fig. F.) When the cells are alive as in sapwood, the passage of liquids through the pits is more or less controlled by the "torus," which is a thickening of the middle portion of the cell wall. When the cells are dead, as in heartwood, the torus ceases to move and frequently becomes fastened to the pit, thus more or less effectively closing the opening to the passage of liquids. Bailey further states that the membranes of the bordered pits are not always entire but possess numerous minute perforations (Fig. 4). "In green wood the bordered pits and membranes are very permeable to aqueous solutions, but are comparatively impervious to undissolved gases and to oils. This is due to capillary or surface tension phenomena and the valve-like action of the torus." The experiments of this investigator throw much valuable light upon the perplexing problem of the penetration of wood and account for some of the results secured in its treatment.

FIG. 4.—Diagrammatic drawing of pit membrane and torus. Note perforations. (From Bailey.)

[1] The Preservative Treatment of Wood," by Irving W. Bailey, Harvard School of Forestry, 1913.

**The Effect of Cell Slits upon Penetration.**—Experiments conducted by Tiemann of the U. S. Forest Products Laboratory[1] show that the walls of wood cells frequently slit open in drying. These slits as a rule are more discernible in thick-walled cells than in thin-walled cells. (See Plate V, Fig. C.) Their presence has been advanced by Tiemann and the author a a possible means of aiding certain liquids to penetrate wood substance, because they furnish points of weakness in the cell wall.

**The Effect of the Chemical Composition of the Cell Wall upon Absorption.**—All the phenomena noted above relate to the physical structure of wood in relation to its absorption of liquids. In addition to them, it is probable, although by no means proven as yet, that the composition of the cell walls in various woods exerts a strong influence upon the manner in which they absorb preservatives. Thus, when the walls are reenforced by subsequent deposits of wood substance, it is quite likely that a different effect is produced than where no such thickening occurs. In addition, the chemical composition of the various layers may be different, as well as the character of the materials deposited upon them. Their combined action, therefore, in retarding oils and water solutions may be a variable one, and hence the character of the absorbtion and penetration obtained may also vary. To just what extent this is true is not known. This problem still furnishes a fertile field for original research.

It can be seen from the above discussion that the manner in which preservatives penetrate wood is very complex. No single factor in itself entirely explains it, so it can be accounted for only by taking several or all of them into consideration.

[1] Bulletin 120, American Railway Engineering Association, 1911.

## CHAPTER IV

## THE PREPARATION OF TIMBER FOR ITS PRESERVATIVE TREATMENT

**The Cutting Season.**—There has been much discussion concerning the effect of cutting timber in various seasons upon its durability. The consensus of opinion gives preference to winter. This is undoubtedly correct in that timber cut at this period is more liable to be in better condition than that cut at any other season. In so far as the contents of the wood cells are concerned, timber cut in winter, as a rule, contains its largest percentage of organic materials, such as starch, these being stored in the cells as available plant food for the next spring. These organic materials are also readily attacked by wood-destroying organisms so that a given amount of winter cut wood, other things being equal, contains more food material for these destructive agents than wood cut at other times of the year.

On the other hand, wood cut in winter is least subject to immediate insect and fungous attack because, during winter, insect and fungous activities are at a minimum. Moreover, freshly cut wood is less able to offer resistance to the attacks of these agents than thoroughly seasoned wood.

Aside from danger from insect and fungous attack, the problem of seasoning is also of great moment, and, as will be shown later on, wood cut during spring, summer, and early autumn dries much more rapidly than wood cut in winter. This rapid drying, unless it is properly safeguarded, will often cause green timber to check and split, thus not only weakening the wood but also exposing more of its surface to attack.

The season of cutting also has a marked effect upon the reproductive power of the forest, especially if the forest is composed of species that sprout from the stump, like most of our hardwoods. Sprouts from winter cut stumps are usually much more vigorous and thrifty than those from stumps cut at other seasons; in fact, the sprouting capacity of stumps can often be killed by cutting timber in summer or early fall.

Contrary to popular belief timber cut in winter often contains as much water and at times, more water, than timber cut at other periods. The common expressions that in winter the "sap is down" and in summer "up" account for this fallacy, whereas in reality it is only dormant, so that if the tree is injured in this period the sap does not readily exude from it. The author made some careful tests along these lines when cutting chestnut timber for poles in Maryland, and found that those cut in winter actually contained more water than those cut in summer.

Generally speaking, it is easiest to remove felled timber from the forests in winter because of climatic and labor conditions, although in the South, where no marked changes occur, this of course is not true. In certain northern states, as in cedar operations in the Lake Region, it is almost impossible to log except in winter. Furthermore, the large amount of timber cut by farmers is felled by them during the winter months because they are not then engaged in caring for their food crops.

**Peeling Timber.**—Practically all preservative processes require the complete removal of bark before the wood can be successfully treated. Generally, the best time to remove the bark is immediately after the tree is felled. In sawed products the bark usually is removed at the mill in slabbing the log. Bark can be removed most easily in the spring (see Plate V, Fig. D), but adheres tenaciously to the wood when cut at other periods. It is comparatively easy for this reason to tell timber cut in the spring. The early removal of the bark lessens the weight of the product, decreases the danger from insect and fungous attack, and causes the wood to dry more rapidly. Because of the great resistance of bark to penetration by liquids, it is essential to carefully and completely remove it, if good results in treatment are to be secured. This is particularly true for those woods which are penetrated readily in a radial direction, as the pines. For species like the tamarack, spruce, etc., whose radial penetration is small, this precaution is not so essential. The author has seen pine piling impregnated with 18 pounds of creasote to the cubic foot that had absolutely no penetration of the oil under strips of bark less than 1/16 inch in thickness. (See Plate VI, Fig. A.) The inner bark or "skin" is particularly resistant, and it is believed that its presence is at times one cause contributing to the rapid failure of those treated piles which are destroyed after a few years' service. Too

often the treating engineer counts on the bark becoming loose during the treatment in the cylinder, and although this frequently occurs, nevertheless it often adheres firmly to the wood and thus results in poor workmanship.

It sometimes happens that better treatments can be secured by seasoning wood with the bark on, rather than with the bark off. This was true in some tests made by the Chicago and Northwestern Railroad on hemlock and tamarack ties at Escanaba, Mich. It appeared that the ties peeled immediately after cutting seasoned so rapidly that the outer layers of the wood hardened and became much more resistant to the absorption of the preservative than those in which the bark was removed just before the ties were run into the treating cylinder. This, however, is an exception to general practice.

Generally, bark is removed by hand, the only tools being a spud, draw knife, or axe. There is a good opportunity for the invention of some machine that will economically and satisfactorily remove bark and thus decrease the labor involved in present methods.

**Seasoning Timber.**—Wood in all living trees contains water. The amount of water thus contained varies with the kind of wood, the conditions under which it grew, and the season. It frequently happens that in the sapwood, and sometimes in the heartwood, the weight of the water is more than the weight of the wood substance itself. Thus the gums when dried may weigh less than half their weight at the time of cutting. In general, as soon as timber is cut it begins to lose the water it contains. This loss of water is called "seasoning." In addition to the loss of water, other changes occur, such as a fixation or transformation of organic and inorganic materials stored in the wood, and an apparent "oxidation" of the wood substance. The objects of seasoning are, in brief:

1. To prevent injury by insects and decay before the timber is placed in service.
2. To increase the durability of timber in service.
3. To prevent shrinking and checking of the wood in service.
4. To increase the strength of the wood.
5. To decrease the weight of the wood and hence reduce shipping charges.
6. To prepare the wood for its injection with preservatives and for other industrial uses.

It is well known that if wood can be kept dry it will not decay. House furniture, for example, under ordinary conditions of use will, so far as decay is concerned, last indefinitely. It is solely because of their protection from moisture that the wooden coffins used by the Egyptians have been preserved to us. Water in wood is an absolute requirement for decay. Wood which can be kept dry. will never decay. Just how much water in wood is necessary in order to meet the requirements of wood-destroying fungi is not known, but from a few tests which the author has made it appears that it is in general more than 20 percent.

It has almost unanimously been held that seasoned wood placed in conditions of service where it is subject to decay wil- last longer than unseasoned wood. While this is sometimes true, nevertheless the importance which has been attached to air seasoning as a means in itself of prolonging the life of wood has probably been exaggerated. Authentic records on posts, poles, ties, and mine timbers kept by the Forest Service indicate that there is little or no difference in their durability whether they were placed green or air seasoned.

If green timber is used for construction purposes, it will almost invariably lose water and hence check, shrink, and warp more or less severely. In order to avoid such defects, it is policy to use seasoned wood in place of green in all classes of construction where they prove objectionable. Furthermore, wood which has been seasoned prior to injection with perservative is far less liable to check on the surface and thus expose the untreated wood.

The effect of water in wood upon its strength is discussed in Chapter XVIII. The decrease in weight due to seasoning is so large as to warrant holding the timber until seasoned before shipment is made. This fact is now so well recognized that it has become common practice, but on account of unfavorable conditions surrounding the seasoning of wood at the place where it is cut, the shipment of green material is sometimes imperative. A single carload of 30-foot chestnut poles if shipped seasoned rather than green would save at least 150 pounds of freight per pole, or, counting 50 poles per car, a total of 7500 pounds. This saving even on short hauls often more than pays for the cost of seasoning the poles and holding them in storage awaiting shipment. What is true for poles is true even to a greater extent for smaller products because they season more thoroughly.

It is in the preparation of wood for injection with preservatives that seasoning plays a very important part, as it is quite essential to remove some or most of the water from the wood before the preservative can be injected.

Water may be considered as existing in wood in two forms: (1) as "free water" in the cell cavities and (2) as "confined water" in the cell walls. When wood begins to season it is the free water which is first lost. Wood can lose all of this free water without its strength being affected. Just as soon, however, as water starts to leave the cell walls the strength of wood begins to increase very rapidly, and checking, warping, and splitting are liable to occur. The point where this occurs has been called by Tiemann the "fiber-saturation point." It varies in the different species but in general ranges from 25 to 30 per cent moisture. When the free water has left the wood, the wood of course contains a larger air space or volume which can later be occupied by a preservative like creosote. This may be illustrated as follows: Assume the oven-dry weight of shortleaf pine is 32 pounds per cubic foot, that solid wood substance weighs 97 pounds per cubic foot, that green shortleaf pine contains 21 pounds of water per cubic foot; then about two-thirds of a cubic foot of green pine would be wood substance and water, leaving about one-third of the volume air space. If, now, all the free water were removed, almost two-thrds ofthe cubic foot of wood would be air space capable of occupancy by the preservative.

Aside from the loss of water which takes place in seasoning, other changes occur. The bordered pits become more or less ruptured, or changed in position, so that passage of liquids through them is facilitated or retarded. Furthermore, the wood cells frequently check as well as the surface of the wood. As a result of these changes which occur in seasoning wood, practically all processes now call for some kind of a seasoning treatment before the preservative is injected. The chief exception occurs in the Boucherizing process, which is at present of no commercial importance in the United States. Five methods of seasoning wood are now practised: Open-air seasoning, seasoning in hot air, seasoning in saturated and superheated steam, and seasoning in oil.

**Open-air Seasoning.**—Open-air seasoning, as the term implies, consists simply in piling the timber out of doors where it is exposed to the atmosphere. When its moisture content reaches

an equilibrium with the atmospheric moisture, the wood is said to be "air seasoned." It can thus be seen that the amount of water in air-seasoned wood varies considerably. Thin pieces of wood 2 inches or less in thickness in our northern climates, when air seasoned, contain about 10 to 15 percent of water. Thicker pieces like poles, ties, etc., are, under the same conditions, "air seasoned" when they contain 25 to 35 percent of water. Some Douglas fir bridge stringers 8 inches × 16 inches in cross section contained over 25 percent of moisture after being exposed to the atmosphere for 2 years.

The open-air seasoning of wood is the method most commonly practised in the United States to prepare it for injection with preservatives. It is cheap, safe to operate, and very efficient. The chief objections to it are the long length of time the wood must be held before it seasons, thus tying up capital in wood and yardage, and dangers from fire, insects, and decay while stored during the seasoning period. In some parts of our country where the climate is warm and damp it is impossible to air-season certain woods without having them attacked by incipient decay. Other objections to air seasoning are an inability to fill "rush orders" and injury from checking, although this latter objection can be largely overcome by proper methods of piling.

To most efficiently season wood in the open air, it is necessary to subject it to a free circulation of air. Stagnant air is very prone to foster decay. The seasoning yards should, therefore, be in situations exposed to the sun and wind. All of the timber should be raised off the ground and should be piled as openly as possible without producing too rapid drying, which might result in serious checking or splitting. Another precaution is to keep the yard free from water, vegetation, and decaying wood.

The rate at which wood seasons depends upon many factors, chief of which is the time of the year. Spring and summer are in general the two periods when most rapid seasoning occurs. More detailed information for the various forest products is given in the following pages under the discussion of these products. When wood has once air seasoned, any water which it might absorb from rains, for example, is quickly lost. Air-seasoned poles tested by the author absorbed 15 pounds of water during a thunderstorm but lost all of it within 24 hours after the rain stopped. It is by no means necessary to season wood until it

has lost all its free water before it is in satisfactory condition for treatment. Large products such as ties and poles may have, when "air-seasoned," an average of 30 percent of water, but the distribution of this water may vary from 5 to 10 percent in the outer layers of wood as a minimum to 40 or 50 percent in the inner layers as a maximum. If a tie or pole is of such a nature (as is customary) that its interior cannot be treated even if it is dry, little or no advantage is gained in attempting to hold it until this condition of uniform dryness is reached. The object, therefore, in open-air seasoning should be to cut the period of drying as short as possible without decreasing the penetration of the preservative. No fixed time can be given for this, as it depends on too many variables which must be worked out for the conditions at each plant.

**Hot-air Seasoning.**—By "hot-air seasoning" is meant kiln drying the wood. This method is now only practised in the United States on certain kinds of lumber and small manufactured products. It is rarely if ever used for large products such as piles, poles, and ties. In Europe, however, the method is sometimes employed, especially as a final drying for timber already partly seasoned in the open air. It is felt that the method will not become common practice in our country because equally as good if not better results can be secured in shorter time and at less expense by other means. The method employed in hot-air or kiln drying consists in placing the wood in a retort or kiln, where the air is usually heated by means of steam coils. Circulation of the air is provided for in various ways, either by blowers, or by cooling the air on the sides of the kiln, or by drawing in air through vents in the bottom of the kiln and permitting the hot air to escape through vents in the top. Such treatment results in removing the water from the wood in much shorter time than open-air seasoning and in addition warms the wood for the entrance of the preservative. Wood so heated is, however, liable to check and warp seriously or case-harden, thus becoming weak and brash. For the treatment of small products of comparatively high value, this method gives very satisfactory results, but for dimension stock or products it has little to commend it.

**Seasoning in Saturated Steam.**—Next to open-air seasoning, seasoning in saturated steam is in most extensive use in the United States as a means of drying wood for the injection of

preservatives. When properly done this method gives quick and satisfactory results. Its chief advantages are the ease, quickness, and comparative cheapness with which the water can be drawn from the wood, the warming of the wood prior to its impregnation, and the sterilizing of the wood. When this method is practised a large storage capacity for wood and a large stock on hand are not necessary. Furthermore, "rush orders" can be taken care of and dangers peculiar to open-air seasoning are avoided. If steamed at too high temperatures or for too long a period, considerable injury may result to the strength of the wood. Steaming wood, in itself, does not remove water from the wood. On the other hand, it may add water, as shown in Table 34. In practice, to remove the water a vacuum is drawn. This lowers the boiling point of water and materially hastens the rate at which it leaves the wood.

Structural timbers, when seasoned for the injection of preservatives by the use of saturated steam, are loaded on cylinder cars or "buggies" and run into the treating cylinder, which is then closed and live steam admitted. The pressures used are about 20 to 40 pounds per square inch. The wood is kept in the steam bath for various periods, depending upon the judgment of the operator, and the kind and form of timber he is heating. It ranges from about 2 to 3 hours for ties to 10 hours or even more for piling. Tests made at the U. S. Forest Products Laboratory indicate that 5 to 8 hours are required to heat ties to the center by this method. After the steam bath a vacuum of 24 to 26 inches is drawn in the cylinder by means of a pump, and at the end of this period the wood is ready for injection with the preservative. The length of time the vacuum is held varies greatly, but is usually from 1/2 to 2 hours. Nothing is gained by holding it after the wood has once reached a temperature below which no further heat units leave the wood.

**Seasoning in Superheated Steam.**—It will be noted that seasoning in saturated steam necessitates a vacuum in order to remove the water from the wood. With superheated steam this is not necessary, as it is capable of absorbing the water vapor driven off from the wood as fast as it is formed. Some of the early wood-preserving plants were equipped with superheaters, but on account of the unskilled labor generally employed, much timber was destroyed by being heated at too high

temperatures and moreover upkeep charges were high. It was largely due to such repeated losses that the use of superheated steam in timber-treating plants fell into disrepute, until its use has now been practically abandoned.

**Seasoning in Oil.**—As with superheated steam, seasoning in oil does not require a vacuum in order to remove the water from the wood. After the wood is run into the treating cylinder and the doors closed, creosote oil is admitted until the cylinder is almost full and all the wood is submerged. Steam is then passed through coils in the bottom of the cylinder and the oil raised in temperature to about 220° F. This gradually vaporizes the water in the wood and the water and certain oil vapors are passed through condensers where the oil can be separated from the water by allowing it to settle. The bath in hot oil is continued, until, in the opinion of the operator, most of the water in the wood has been removed. Some operators continue the seasoning in oil until the amount of water condensed does not exceed one-sixth of a pound per cubic foot of wood per hour. The cylinder is then filled with oil and the preservative injected under pressure. At the present time this method of seasoning is practically confined to certain plants on the Pacific Coast, where it is claimed to give very good results, especially with refractory woods like the Douglas fir. In addition to seasoning the timber, this method also warms it for the reception of the preservative. It appears that this process may cause the wood to check microscopically and hence reduce its strength. This however, is discussed at length in Chapter XVIII.

**Soaking Timber in Water Preparatory to Seasoning It.**—If freshly cut timber is soaked in water some of the soluble constituents which it contains will be leached from the wood. The wood cells will, therefore, contain a larger percentage of air space so that resistance to absorption of preservative after the wood has been seasoned will be decreased. In order to make this difference one of any appreciable amount, it is necessary to soak the timber for long periods of time. In addition to rendering the wood more permeable to preservatives, it also causes the wood to season with accelerated rapidity after it is removed from the water. Short periods of soaking varying from 2 weeks to 2 months are productive of little or no beneficial results. This method has been tried on poles and ties, and although they lost weight very rapidly when first removed from the water, nevertheless they

failed in the long run to show any appreciable decrease in weight over similar timber not soaked. Furthermore, the amount of preservative which they absorbed in excess of that absorbed by timber unsoaked was so small (about 1/2 of 1 percent) as to be of no practical value. Unless a treating plant is so situated that it can afford to hold timber in storage for long periods prior to its impregnation, or unless water soaking can be conducted (as in rafting timber) at a very small or no extra cost, it appears that water soaking as a means of preparing wood for treatment is not justified by the results secured.

## CHAPTER V

## PROCESSES USED IN PROTECTING WOOD FROM DECAY

Although a great many processes have been and are practised in protecting timber from decay, they may be logically divided into two rather distinct groups, based upon the character of the protection given. These may be termed the superficial and the impregnation processes.

**Superficial Processes.**—By superficial processes is meant those processes of treatment which aim to protect the wood by simply giving it a surface protection. Since in sound timber decay can occur only from external attack, it is agreed that if the surface of the wood is rendered resistant to the attack of wood-destroying fungi, the entire timber will remain sound. This contention is without doubt correct, and when the surface of a timber is so preserved and the surface protection is completely maintained, the timber may be made to last indefinitely. Unfortunately, timbers so treated are very apt to have the protective coating broken, either through abrasion or checking. When this happens the untreated interior is at once subject to attack, and the effect of the protecting shell may be completely destroyed. In this condition, the timber may be very dangerous, as it gives the appearance of being sound although it may be entirely decayed in the interior, and hence escape detection. The writer has seen mine timbers painted with a preservative that appeared on outward inspection to be perfectly sound, but when bored into, were found to be little more than hollow columns because the wood beneath the surface had entirely rotted. Furthermore, it is not always possible to detect incipient decay in wood to be treated. In fact, this is often impossible without a microscopic examination, which is, of course, impracticable in practice. If such wood is given a superficial treatment, the incipient decay in the interior is liable to continue its growth and thus the soundness of the wood will eventually be destroyed. These objections can be levied against all superficial processes.

On the other hand, it is often impossible to treat wood in any

other way because of excessive cost. Superficial processes are of special usefulness when only a small quantity of wood is to be treated. They are cheap, easily conducted, and under ordinary conditions, efficient. When the surface of the wood is not subject to injury by abrasion or checking they succeed in greatly prolonging the life of the wood.

**Charring.**—Charring is one of the oldest methods of protecting timber from decay that has been practised. The wood is held over a fire until the outer fibers are charred. This process practically surrounds the wood with a layer of charcoal which is not attacked by wood-destroying fungi. The heat, furthermore, destructively distills a portion of the wood and forms products which may be toxic to fungi. The depth to which the wood is usually charred varies from about 1/8 to 1/2 inch. Much more effective results can be secured by charring seasoned wood rather than green wood, as the latter will dry out on exposure and develop surface checks, which will break the continuity of the charred surface and thus expose the untreated interior. When air-seasoned wood is properly charred its life is increased. The treatment is very cheap and easily applied. It has a disadvantage, however, in that it completely destroys the strength of the outer fibers of wood and so weakens the wood. Furthermore, the beneficial effects secured from it are seldom of much consequence.

**Brush Treatments.**—Brush treatments are more extensively practised than any other of the superficial processes. (See Plate VI, Fig. B.) As the term implies, they consist in painting the preservative on the surface of the wood with a brush. A large variety of preservatives are applied in this manner, such as calcimine, wood preserving oils, paints, etc. Best results are secured by treating only air-seasoned wood, thus avoiding danger of subsequent checking. Moreover, the preservative will penetrate dry wood better than green. With certain preservatives, such as creosote, most beneficial results are obtained by heating them to 180° or 200° F. before they arepainted onto the wood, as they penetrate more deeply when applied hot. The penetration, however, seldom exceeds 1/4 inch and is generally much less. Brush treatments can be easily applied, are cheap and convenient. In using them care should be taken to coat all checks, cracks, and joints thoroughly with the preservative. The preservative should not be applied when the wood is frozen and

wet. If an efficient preservative is used and properly applied and the wood after treatment is protected from abrasion, very satisfactory results can be expected. Unless these precautions are exercised, the treatment may do no good whatever, but may actually result in harm. Thus, unseasoned telephone poles have been examined which were coated with ordinary paint and which had decayed quicker than similar poles set unpainted. In this case the poles checked after they were treated, allowing fungi to enter, while the paint formed an almost impervious coating which kept the wood moist and hence in a very favorable condition for rapid decay.

**Dipping.**—In view of the difficulty of working the preservative into checks and cracks, dipping gives more effective results than brush treating. To dip wood, however, it is necessary to have some form of tank which will hold the preservative and which is large enough to allow the wood to be submerged. This method of treatment is particularly adapted to small products such as shingles and posts. The same precautions mentioned under brush treatments apply with equal force to dipping treatments. On account of the greater certainty with which the entire surface of the wood can be treated, dipping is safer to use than brush treating and, in general, yields better results.

**Impregnation Processes.**—All impregnation processes aim not only to protect the surface of the wood from attack but also to force the preservative deeply into the wood. Thus, should the surface of the wood become broken, the fibers beneath the surface containing the preservative will still offer a strong resistance to decay. For this reason all impregnation processes are, as a rule, more efficient than superficial processes. The depth to which the preservatives will penetrate depends on many factors, chief of which are the kind and condition of the wood, the character of the treatment, and the kind of preservative used. Nonresistant woods like heart Douglas fir or white oak may, under similar conditions, only receive a superficial treatment.

By far the largest quantity of wood treated in the United States is impregnated. Impregnation processes are much more expensive than superficial processes and require more or less elaborate apparatus. In connection with large operations, however, they are unquestionably the better ones to use and the results secured by them are the best obtainable. For purposes

FIG. A.—Sections of creosoted piling showing effect of thin strips of bark adhering to the wood. (Photo through courtesy Southern R. R.)

FIG. B.—Brush treating poles. (Forest Service photo.)

(Facing page 52.)

PLATE VI

FIG. C.—An open tank plant for treating the butts of poles—California. (Forest Service photo.)

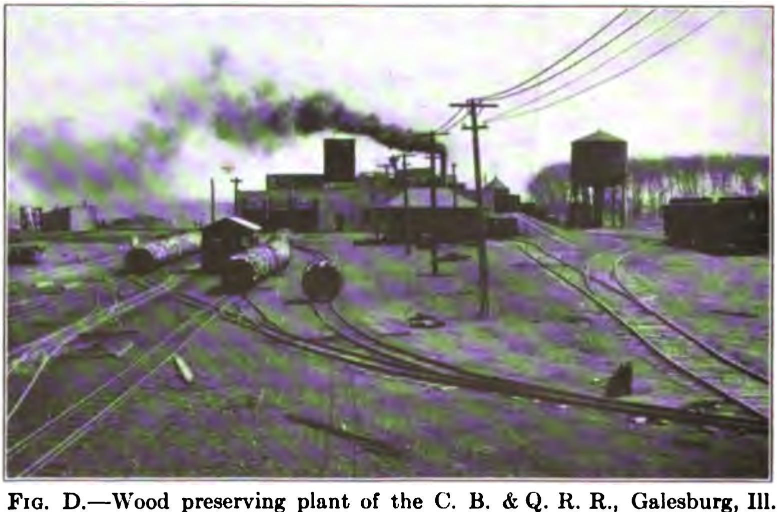

FIG. D.—Wood preserving plant of the C. B. & Q. R. R., Galesburg, Ill. (Forest Service photo.)

of discussion, impregnation processes may be divided into two classes, (1) nonpressure processes, or those using no "artificial" but only atmospheric pressure, and (2) pressure processes, or those using "artificial" or pressures greater than atmospheric.

**Nonpressure Processes.**—These processes either rely upon the absorptive properties of the wood for the penetration to be secured, or upon the pressure of the atmosphere to force the preservative into the wood. Heavy apparatus to withstand pressures is therefore unnecessary and this fact enables plants operating on this basis to be built at lower cost than those operating on high pressures. This is one of the chief advantages claimed for this method of treatment. The apparatus may be an open vessel such as a barrel or a vat, or a cylindrical retort of metal similar in form to those used in the pressure processes. For the treatment of small quantities of timber, or when salts markedly corrosive to iron are used, or when only a portion of the timber is to be treated, the rest being left untreated, these processes give very satisfactory results. As a rule the penetrations and absorptions obtained with them are not as deep or as uniform as those obtained in the pressure treatments, although, at times, equally as good results in this respect are secured. The time of treatment is also generally longer and the flexibility and control of the plant less than with pressure processes.

**Kyanizing Process.**—This process has been in use since 1832 when it was patented in England by John H. Kyan. It was employed in the United States as early as 1840 and is claimed to be the oldest method of treating timber now practised in our country. The process consists in steeping timber in a solution of bichloride of mercury at atmospheric temperature and pressure. At Portsmouth, N. H., and Lowell, Mass., the treating apparatus consists of solid granite tanks laid in Portland cement and coated on the inside with tar applied hot. The wood to be treated is piled in the tanks with laths between each layer so as to allow the free circulation of the solution, which is afterward pumped into the tanks. The strength of the solution is usually about 1 percent. The timber is kept submerged for various lengths of time but a rough estimate is to steep it 1 day plus a day for each inch in thickness. Thus 2-inch plank is steeped 3 days, 6-inch timber 7 days, etc. The depth to which the solution penetrates varies largely with the kind of wood treated but ranges from about 1/10 to 1/4 inch. The extremely poison-

ous nature of mercuric chloride makes it imperative to handle it with caution. Its corrosive action, moreover, makes its use impracticable in iron or steel vessels unless specially prepared. Like all treatments employing a water-soluble salt, it cannot be used to best advantage if the timber is to be set in wet situations, because the solution will leach from the wood. When the treated wood is placed in fairly dry situations, very good results have been reported. There is also a liability of the salt gradually crystallizing on the surface of the wood where it may prove dangerous to animals should they lick it. Although large quantities of timber have been treated by this process, its use in this country has never been very extensive. This is perhaps largely due to its extremely poisonous character and the comparatively long time it takes to treat the wood. Cases are on record where it is reported that spruce posts, Kyanized, have remained serviceable for over 50 years, and hemlock ties for over 13 years.

**Open-tank Process.**—Under this heading we will consider several processes which are very similar so far as the principles of treatment are concerned. They are the Seeley, Giussani, and nonpressure processes. All of these processes differ in principle from the Kyanizing process, in that they aim to employ the pressure of the atmosphere in forcing the preservative into the wood. (See Plate VI, Fig. C.) Green or air seasoned wood may be used. It is first placed in a bath of hot oil and held for various periods, the object being to drive a part of the air, sap, and water out of the wood and thus bring the wood cells into a rarified condition. The heated timber is then quickly submerged in a cool preservative, whereupon a rapid contraction of the air and water vapor in the wood occurs, thus "drawing in" the preservative.

Professor Seeley of New York is reported the first to make use of this principle on a commercial scale, he having secured patents on it in 1868. Seeley used creosote oil and claimed to treat either green or seasoned wood. (See Chapter I for further discussion.)

About 1898 Tomasco Giussani invented a similar process in Italy which he claimed made possible the impregnation of timber with dead oil of tar alone, with salt solutions alone, or combinations of the two. Open tanks are used and the process is a continuous one. The timber either green or seasoned is carried by a conveyor to the first tank, which contains heavy

creosote oil heated to about 280° F., where it is kept submerged until ebullition ceases (a period of from 1 to 4 hours). It is then conveyed mechanically to another open tank containing cold creosote oil or zinc chloride or any other preserving salt until the desired absorption has been obtained (a period of from 2 to 3 hours), after which the treatment is finished and the timber is mechanically removed from the treating vats. This process was demonstrated at the St. Louis Exposition in 1904 where it was awarded a Grand Prize. Two plants operating on this process are located in Rome and Milan, Italy, but so far as the author knows, it is not practised in the United States. By this method of treatment deep penetrations of the preservative are possible, which, in certain timbers like loblolly pine ties, may extend to the center. In plants operating on this basis the diffusion and absorption of the preservative cannot be as practically controlled as in pressure plants, but for a low initial cost of installation they are efficient.

In 1904 the U. S. Bureau of Forestry (now the Forest Service) conducted an extensive series of tests with what is called the "open-tank" process at the St. Louis Exposition.[1] This method of treatment has since been extensively tested by the Forest Service with a view to perfecting it and evolving a process which could be efficiently used by the small consumer. It secured its name from the character of the apparatus in which the treatments are made, these being open tanks of any convenient size and shape. Later experiments lead to the use of closed tanks or cylinders for certain treatments and the term "nonpressure" was employed to designate the process carried on in them. In principle, therefore, it differs in nowise from any of the "open-tank" processes. In open-tank treatments the Forest Service recommends only the use of air-seasoned wood. This is subjected to a bath in hot creosote, but temperatures above 250° F. are not recommended as they are liable to injure the wood. The wood is then either allowed to remain in the hot oil, which is gradually cooled, or else changed to a tank containing cool oil, or cool oil is pumped into the tank containing the timber after the hot oil has been removed. The process is adapted to the use of various preservatives such as creosote, crude oil, zinc chloride, etc. Very good penetrations are secured, in fact these compare favorably with

[1] Circular 101, "The Open-tank Treatment of Timber," by Carl G. Crawford, Washington, D. C.

those secured in pressure processes. This process is admirably adapted to the treatment of poles and posts where only a portion of the stick is to be treated. Plants operating on this basis are comparatively cheap. It is possible to control fairly accurately the character of the penetration and absorption, especially in woods which lend themselves readily to treatment, like sap pine. For example, if a deep penetration is desired with a comparatively small absorption of oil, the timber should be left in cool oil for only a short period after it is removed from the hot bath. Another way is to re-treat the wood after it has been treated in cool oil. This tends to drive out a part of the oil in the wood provided it is removed from this second hot bath while it is still hot. If a heavy absorption is desired, the wood should be heated thoroughly and then submerged in cool oil until the temperature of the wood has reached that of the oil.

If it is desired to impregnate the wood with a water-soluble salt like zinc chloride, this may be done by boiling the wood in the solution (which, however, is very apt to weaken it) and then allowing it to cool, or by boiling the wood in oil for a short time and then submerging it in a solution of the salt. In this way a deep penetration of the salt can, at times, be secured, while the outer portion of the wood will have an added protection due to the small amount of oil which it contains.

The length of time required to treat wood by the open tank method is very variable, but a hot bath of 1 to 3 hours followed by a cool bath of the same or a longer period is usually sufficient. A number of open-tank plants are now in operation in the United States, chiefly by farmers and mine and telephone companies.

**Pressure Processes.**—All processes so classed rely upon the use of pressures above atmospheric in order to force the preservative into the wood. (See Plate VI, Fig. D.) In general, best results are secured by such treatment, although it is by no means possible to satisfactorily penetrate all woods even with the use of high pressures.

*Bethell (Full-cell Creosote) Process.*—This process is named after John Bethell who took out patents in England in 1838. It is commonly referred to in our country as the "full-cell process." Either green or seasoned timber can be treated by this process, creosote oil (dead oil of coal-tar) being the preservative used. The timber to be treated is loaded upon steel

cars or "buggies," which are run into horizontal steel cylinders usually 7 feet in diameter by 132 feet long. Their length, however, varies from about 50 to 180 feet and diameter from 6 to 9 feet. If the timber is green, it is subjected to a bath of live steam for several hours, after which a vacuum is drawn by means of pumps. This also is held for one or more hours according to the judgment of the operator. If the timber is air seasoned, the steam bath is generally omitted. Creosote oil is then run or pumped into the cylinder and a pressure of 100 to 180 pounds applied until the gauges show the desired amount of oil has been forced into the wood. The excess oil is then drained from the treating cylinder and the timber is allowed to drip for a short period, after which the process is ended and the charge is removed. Many treating engineers draw a vacuum in the cylinder after the excess oil has drained from it, as this tends to hasten the drip and dry the timber. The Bethell or full-cell process is considered the standard process of treating timber with creosote, and the most effective results in prolonging the life of wood have been secured by it. On account of the relatively large amount of oil which the ties absorb, the process is, however, the most expensive and for this reason several modifications have been made.

*Boiling Process.*—This process was patented in the United States by W. G. Curtis and John D. Isaacs and the patent number was reissued November 1, 1895. It is used almost exclusively on the Pacific Coast, largely for the treatment of Douglas fir. Either green or seasoned wood can be treated, although the former is at present in more extended use. The wood is run into cylinders as in the Bethell process and immersed in creosote oil heated at the start to about 160° F. A space of about 10 inches is left clear from the top of the oil to the top of the treating cylinder. The oil is heated by means or steam coils in the bottom of the cylinder and the temperature gradually raised to about 225° F. The vapors of oil and wates passing over are condensed in a surface condenser. The oil if kept at a temperature of about 225° F. until the rate of evaporation does not exceed about 1/6 of a pound of water per cubic foot of wood in the charge per hour; this being to drive the sap and water out of the wood. The treating cylinder is then filled with creosote oil at a pressure of 5 pounds per square inch, the temperature falling to about 200° F. The pressure

pump is then started and held at about 150 pounds per square inch until the gauges show the desired amount of oil has been forced into the timber. After injection, the pressure is slowly released through an overflow pipe, the excess oil drawn from the cylinders, and the charge removed. In treating dry sawn timber, temperatures above 214° F. and pressures over 120 pounds per square inch are not recommended by the advocates of this process. It can thus be seen that the boiling process resembles the Bethell process except for the preliminary treatment which the timber is given.

*The Buehler Process.*—Walter Buehler secured two patents in the United States on September 22, 1908 (Nos. 899237 and 899480) on the process which bears his name. Either green or seasoned timber can be treated, the preservative being creosote oil. The process is not at present in extended use. Green or water-soaked timber is treated as follows. It is run into the treating cylinder as in the Bethell process and immersed in creosote heated to a temperature of not less than 140° F., the cylinder being completely filled with oil. The temperature of the oil in the cylinder is kept gradually rising as fast as the condensation will permit until it reaches between 220° and 260° F. It is then held to maintain a regular and constant temperature within the cylinder. During this seasoning period the gauge on the cylinder should show a pressure of not more than 5 pounds. The maximum temperature is maintained until the condensation in the hot well shows the interior of the wood "to be sufficiently dry," when the steam in the coils is released and the cylinder filled with creosote, the temperature being lowered to about 200° F., when the pressure pump is started and the oil is forced into the wood until the desired amount has been absorbed. The cylinder is then drained of excess oil and an air pressure of 15 to 25 pounds per square inch is applied and held to penetrate all of the wood. This completes the process.

For air-seasoned timber, a vacuum of at least 20 inches is drawn after the wood is placed in the cylinder, and held for at least 20 minutes. Creosote is then admitted and pressure applied with the force pump until the proper amount of oil has been injected. The excess oil is then drained from the cylinder and an air pressure of 15 to 25 pounds is maintained until the

maximum pressure remains constant for at least 15 minutes, after which the treated timber is removed from the cylinder.

Tests made by the author showed that air pressures applied to wood freshly impregnated with creosote forced much of the creosote out of the wood after these pressures were released and greatly prolonged the time it took the timber to drip.

*The A. C. W. Process.*—In the A. C. W. process, so called after the American Creosote Works in Louisiana in which it is practised, after the timber has been subjected to a preliminary seasoning of live steam, and after a vacuum has been drawn, air is forced into the cylinder until a pressure of about 15 pounds is obtained. Creosote is then admitted, the air pressure being still maintained to prevent excessive or unequal absorption of the oil while the cylinder is being filled. The surplus air is allowed to escape through a pop valve at the top of the cylinder. When the cylinder is full of oil a pressure of 100 pounds or more is applied with a pump until the proper amount of the creosote has been forced into the timber. The oil is then run from the treating cylinder and an air pressure of 60 to 80 pounds applied. This is introduced to drive the oil into the wood to a greater depth and to secure greater uniformity of treatment.

The process is not in general use and is practically confined to the plant operated by the American Creosote Works.

*The Lowry Process.*—This process is covered in the United States by Patent No. 831450, issued to C. B. Lowry under date of September 18, 1906.

Air-seasoned timber is loaded on tram cars and placed within the treating cylinder. The cylinder is then filled from the charging tank with creosote oil at a temperature not to exceed 200° F. The main line is then closed and oil from the charging tank is forced by pressure pumps into the retort until the timber has taken oil to the point of refusal, or a predetermined amount. The pressure and temperature within the retort are controlled so as to give a maximum penetration of the oil. The pressure is then released and the free oil in the retort is drained off. A vacuum of sufficient degree and duration is then drawn in the retort to recover that portion of the free oil in the timber above the specified amount. The recovered oil is then drained off from the retort and the charge is withdrawn. The Lowry process may be termed an "empty-cell" process in that it aims to secure a deep penetration of

creosote without consuming as much of it as the Bethell or full-cell process. At the present time the process is in very extended use in the United States, particularly in treating cross-ties, eleven plants now operating under its patent.

*Rueping Process.*—This is also termed an "empty-cell" process in that the object sought is a deep penetration of creosote with a comparatively small consumption of the oil. It was patented in the United States on September 23, 1902, the issue being to Messrs. Halsberg & Co., M. B. H., of Germany. The timber to be treated should preferably be air-seasoned. Green or partially seasoned wood is subjected to a steam and vacuum bath similar to that given in the Bethell process before the treatment is begun. After the timber has been placed in the treating cylinder, compressed air is admitted frequently from an overhead tank and held until the wood is filled with compressed air. Creosote is then admitted under a slightly higher pressure, the air in the cylinder gradually escaping. When the cylinder is filled with creosote the pressure on the oil is raised to about 150 or more pounds and held until no more oil can be forced into the wood. The cylinder is than drained of oil and a final vacuum drawn to increase the expansive force of the air in the timber and to dry the wood as quickly as possible. The length of time the compressed air is held, the pressure of the compressed air, the length and pressure of the oil period, and the length of the final vacuum all vary with the kind of timber under treatment. When they are properly adjusted, penetrations as deep as those secured in the Bethell process are obtained, in some cases with one-half or less the consumption of oil. Rueping-treated timber has a tendency to drip much longer than timber treated without the use of compressed air, and the rate of evaporation of the creosote from it is also likely to be greater. The process is now in extended use in both the United States and Europe.

*Burnett Process.*—William Burnett patented this method of treatment in England in 1838 and it has been in constant use since. It is commonly referrred to as the standard process using a water-soluble salt, chloride of zinc. The method of treatment is exactly analogous to the Bethell process, the only essential difference being in the character of the preservative. As a general rule, water solutions can be forced into wood deeper than oils, so that under any given set of conditions slightly better penetrations are secured from the use of zinc chloride than from

creosote. The Burnett treatment is in extensive use in the United States and Europe, where it has given excellent results in prolonging the life of timber not set in very wet conditions. On account of the soluble nature of the salt, several methods have been employed to retard its leaching action, some of which are now extensively practised.

*Rutgers Process.*—The objections of the comparatively high cost of creosote and the leachability of zinc chloride are both partially overcome by the Rutgers process, invented by Julius Rutgers in Germany about 1874. Rutgers handles the timber to be treated in much the same way as is done in the Bethell process, but employs a mixture of zinc chloride and creosote as his preservative. The zinc chloride is generally in a 3 to 5 percent solution and comprises about 80 percent of the mixture. To this a comparatively low-gravity creosote free from naphthalene is added by means of a jet of steam or air or other suitable mixing device. The timber thus treated contains both creosote and zinc chloride injected simultaneously. While the process is not practised in the United States, it has found extensive use in Germany, where it is reported to give marked satisfaction, particularly in the treatment of cross-ties.

*Card Process.*—The principle of injecting timber simultaneously with zinc chloride and creosote was adopted by J. B. Card, to whom a patent was granted in the United States on March 20, 1906. Card's process differs essentially from that of Rutgers in the manner of keeping the solution mixed. He uses about 80 percent of zinc solution to 20 percent of creosote, the strength of the zinc being regulated so that approximately 1/2 pound of the dry salt will be injected with each cubic foot of wood treated. This solution is first mixed in the measuring tank by forcing air through perforated pipes placed on the bottom. When the solution is run into the treating cylinder, the agitation is continued by means of a centrifugal pump which draws it from the top of the retort and returns it through a perforated pipe running lengthwise in the bottom of the cylinder. The steps in the Card process are analogous to those in the Bethell process. Air-seasoned timber is advocated. After this is run into the cylinder a vacuum of 22 to 26 inches is drawn for about 1 hour. The preservative mixture is then admitted at a temperature of about 180° F. and a pressure of about 125 pounds per square inch applied to it by means of force pumps for 3 to 5 hours, or until the desired

absorptions have been secured. During this period, the centrifugal pump is kept running in the manner described above, to agitate the solution in the cylinder. The cylinder is then drained of excess preservative and a final vacuum drawn to assist in drying the timber, after which the charge is removed. Difficulty may be experienced in keeping the solution uniform during treatment, unless the proper conditions are maintained. Good penetrations of both creosote and zinc chloride are secured in this process, which is now extensively used in the United States, particularly for the treatment of cross-ties.

*Wellhouse Process.*—Experience with the Wellhouse or zinc-tannin process began about 1881, when some ties were treated in St. Louis, Mo. In the early 80's and 90's this method of treatment was extensively used in the United States but at the present time the amount of timber treated by it is comparatively small. The chief objections to its use were apparently the many manipulations required and the difficulty of satisfactorily operating them.

The timber to be treated is handled much the same as in the Burnett process except for the manipulations of forcing the preservative into the timber. After the timber has been placed in the treating cylinder and seasoned, as in Burnettizing, a solution of zinc chloride and glue in the proportions of 1 1/2 to 3 percent of the former to one-half of 1 percent of the latter is forced into the wood by means of pressure pumps under a pressure of about 125 pounds per square inch and held for 3 to 6 hours. The excess preservative is then drained from the cylinder and a water solution of one-half of 1 percent tannin is introduced and forced into the timber at 125 pounds pressure for about 2 hours, after which the excess tannin solution is drained from the cylinder and the charge removed. The tannin combines with the glue and forms a "leathery substance" which tends to plug up the pores of the wood and retard the zinc chloride from leaching out. The process was later modified by injecting the glue separately, it being found that it retarded the entrance of the zinc solution. The temperature of the treating solution as well as the strength of the zinc chloride used was also raised.

While the mixture of glue and tannin does tend to plug the wood cells, nevertheless, the extent to which they do this has been exaggerated. The zinc-chloride solution not only resists the entrance of the glue and tannin in subsequent injection, but the air confined in the wood tends to push the plug out of the

cells due to its expansive force. Microscopic examinations of Wellhouse-treated wood have shown that the "plug" is only a surface coating and seldom actually extends into the timber. While very good results have been secured from this method of treatment, it is believed that better results could have been obtained if a strong preliminary vacuum had been drawn and held while the zinc solution was entering the cylinder. The Wellhouse process is comparatively cheap, costing about 18 cents per tie, and has succeeded in more than doubling the life of ties which like hemlock, red oak, and gum decay very rapidly.

*Allardyce Process.*—So called after R. L. Allardyce, who suggested its use. The timber to be treated is handled much as in the Wellhouse process except that creosote instead of glue and tannin is used. A 4 percent zinc-chloride solution is forced into the wood at a pressure of about 130 pounds per square inch, after which the cylinder is drained and refilled with creosote, this being injected under a pressure of about 180 pounds per square inch so as to form a continuous outer layer around the zinc-treated timber. As might be expected, the penetration of the creosote is slight. If, however, the timber is removed from the cylinder after its injection with zinc chloride and allowed to air season, and then re-treated with creosote, better results are obtained. The delay thus occasioned and the increased cost of handling then become serious objections. The Allardyce process is not in extensive use at this time.

The author treated a number of red oak and maple ties by reversing the Allardyce method. These were first impregnated with 2 to 3 pounds of creosote per cubic foot, after which the cylinder was drained and refilled with a 3 percent zinc-chloride solution forced into the wood until 1/2 pound of the dry salt was injected. The cylinder was drained and the charge removed. The results secured were very similar to those obtained in the Card process, much of the creosote being carried further into the wood. By this manipulation, delay in treating and increased cost of handling are avoided, but unless extreme care is exercised the zinc-chloride solution will soon become contaminated with the creosote, so that the amount of each consumed will become a matter of speculation.

## CHAPTER VI

## PRESERVATIVES USED IN PROTECTING WOOD FROM DECAY

**Properties of Efficient Preservatives.**—Hundreds of chemicals and compounds have been advocated and tested to preserve wood from decay, but only a few of them possess sufficient merit to justify their use for this purpose. As was shown in Chapter II, decay in timber is caused by fungi and bacteria. To preserve wood from decay it is therefore absolutely essential to protect it from the attacks of these organisms. In brief, all fungi and bacteria which decay wood require certain amounts of heat, air, moisture, and food in order to live. If one or mose of these essentials can be eliminated, these organisms cannot live and hence wood will remain sound indefinitely. The basic problem, therefore, in any efficient preservative process is to accomplish this. Obviously a control of heat and air around structural timber set subject to decay is exceedingly difficult and generally impracticable. Hence a control of the moisture in the wood and the food of the fungus (which is the wood substance) are the two most practical lines of preventing attack. Wood kept constantly under water is too wet to permit the fungi to grow and hence will remain sound *ad infinitum*. Conversely, wood kept constantly air dry or drier contains too little moisture for fungous growth and will never decay—to wit, the durability of furniture in dwellings, etc. All successful wood preservatives, therefore, either keep the wood comparatively dry or else poison the wood so that the organisms attacking it are killed.

The amount of moisture in wood necessary for the growth of wood-destroying fungi is not definitely known. It is the author's opinion that in general it must be not less than 20 percent. Certain fungi which have the ability of making or transporting moisture may be able to attack wood containing a smaller moisture content than this. It is well known that posts set in the ground decay in or near the ground and rarely in the top. To secure some data on the distribution of moisture in posts, the author placed several cedar posts in the ground and took

moisture borings 2 inches deep 2 feet below ground level, at ground level, and 3 feet above ground level, at various periods extending over a year. That portion of the posts buried in the ground contained in general about 30 percent moisture, that near the ground line about 32 percent, and that near the top less than 17 percent. If, then, wood can be impregnated or coated with a substance that will keep it comparatively dry, the fungi and bacteria will be unable to develop and the wood will remain sound. This is the basic principle involved in the use of nontoxic oils, like petroleum.

In general, most effective results in prolonging the life of timber from decay are obtained by using some chemical which is toxic and which thus poisons the food of the fungus. Toxic preservatives differ considerably in their effectiveness against fungi. Considerable work has been done by a number of investigators to determine the smallest amount of preservative necessary to inhibit fungous growth. This is called the "toxic limit." One of the most satisfactory methods of doing this is by means of cultures in glass dishes by what is known as the "petri-dish method." It consists, in brief, in pouring into the sterilized petri-dishes a solution of agar-agar of the following approximate composition: Juice from 1 pound of beef, 25 grams of Löfflund's malt extract, 20 grams of agar-agar, and 1000 c.c. of distilled water. Upon this medium is placed a small mat of fungus mycelium. The dish thus inoculated is placed in a constant temperature oven for about 6 weeks. Various amounts of the preservative to be tested are weighed on a chemical balance and mixed into the culture medium. The fungus will grow readily on low concentrations but a concentration is finally reached above which no growth occurs. The smallest concentration which inhibits growth is called the "toxic limit" or "toxicity" of the preservative. A number of preservatives have been tested in this manner by C. J. Humphrey at the U. S. Forest Products Laboratory, the results being given in Table 4 The greater the toxicity of a preservative, the greater is its ability to kill fungi and keep wood sound. It frequently happens, however, that those preservatives which are most toxic are not the ones which give best satisfaction in prolonging the life of wood, because they may have certain inherent characteristics which vitiate or preclude their use. Chief among these are their permanency, and corrosion of iron.

TABLE 4.—THE TOXICITY OF VARIOUS PRESERVATIVES ARRANGED IN ORDER OF RATIO TO COAL-TAR CREOSOTE

| Preservative known as | Toxic limit (killing point) | | | | | |
|---|---|---|---|---|---|---|
| | Fungus used | | | | | |
| | Fomes annosus | | Ratio to coal-tar creosote No. 1074 | | Fomes pinicola | |
| | Percent | Lbs. per cu. ft. | | | Lbs. per cu. ft. | Percent |
| Coal-tar creosote, Fraction II, sp. gr. 1.003 | 0.225 | 0.140 | 2.5 | 1.5 | 0.094 | 0.15 |
| Sodium fluoride | 0.25 | 0.156 | 2.2 | 1.5 | 0.094 | 0.15 |
| Cresol-calcium | 0.14–0.28 | 0.087–0.174 | 3.9–2.0 | ........ | ........ | ........ |
| Coal-tar creosote, Fraction I, sp. gr. 0.934 | 0.30 | 0.187 | 1.8 | 1.0 | 0.140 | 0.225 |
| Coal-tar creosote, Fraction III, sp. gr. 1.045 | 0.325[1] | 0.203 | 1.7 | 1.8 | 0.078 | 0.125 |
| Water-gas tar creosote, sp. gr. 0.995 | Around 0.45 | ........ | ........ | ........ | ........ | ........ |
| Zinc chloride | 0.50 | 0.312 | 1.1 | 0.3 | 0.468 | 0.75 |
| Zinc sulphate | Around 0.50 | ........ | ........ | ........ | ........ | ........ |
| Coal-tar creosote | 0.55 | 0.343 | ........ | ........ | 0.140 | 0.225 |
| Wood creosote | 0.65[1] | 0.405 | 0.84 | 1.12 | 0.125 | 0.20[1] |
| Wood tar | 1.25 | 0.78 | 0.44 | 0.3 | 0.468 | 0.75 |
| C. A. Wood Preserver | 1–1.5 | 0.6–0.9 | 0.55–0.37 | ........ | ........ | ........ |
| Spirittine wood preserver | 1–2 | 0.6–1.2 | 0.55–0.27 | ........ | ........ | ........ |
| S. P. F. Carbolineum | 2.25 | 1.404 | 0.24 | ........ | ........ | ........ |
| Holzhelfer | Above 2.5 | ........ | ........ | ........ | ........ | ........ |
| Coal-tar creosote, Fraction IV, sp. gr. 1.088 | 3.3[1] | 2.059 | 0.16 | 1.8 | 0.078 | 0.125[1] |
| Water-gas tar creosote, sp. gr. 1.042 | 3–4 | 1.9–2.5 | 0.18–0.14 | ........ | ........ | ........ |
| Avenarius Carbolineum | 5.25 | 3.27 | 0.104 | 0.75 | 0.187 | 0.30 |
| Fuel oil | Above 6 | ........ | ........ | ........ | ........ | ........ |
| Kerosene | Above 34 | ........ | ........ | ........ | ........ | ........ |
| Coal-tar creosote, Fraction V, sp. gr. 1.150 | 33[1] | 20.59 | 0.017 | 0.029 | 4.867 | 7.80[1] |
| Copperised oil | 40 | 24.96 | 0.015 | 0.0056 | 25+ | Above 40 |
| N. S. Special | Above 45 | 28+ | 0.014– | 0.0045 | 31.2+ | Above 50 |
| Water-gas tar creosote, sp. gr. 1.058 | Above 40 | 25+ | 0.016– | 0.0056 | 25+ | Above 40 |
| Sapwood antiseptic | Above 75 | 46.8+ | 0.007– | ........ | ........ | ........ |

[1] Tests not duplicated. Specific gravity taken at 60° C.

Practically all inorganic preservatives are soluble in water, and will, if exposed to ordinary atmospheric conditions, leach out of wood. If they should do this at a rapid rate, the wood will soon be left unprotected so that the fungi can attack it. In order to be effective, therefore, such preservatives must remain in the wood for long periods.

While organic preservatives are, as a rule, insoluble in water many of them volatilize when exposed to the atmosphere, so

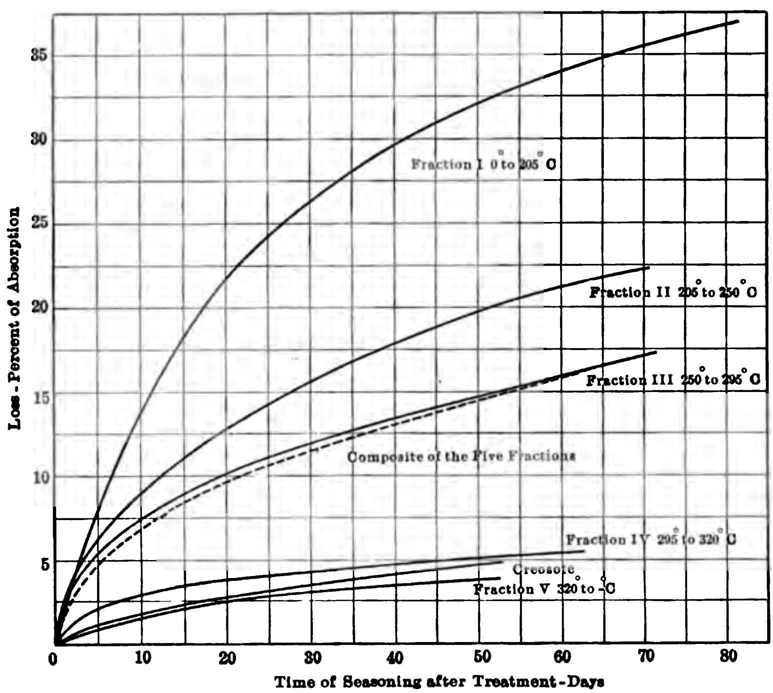


FIG. 5.—Comparative rates at which fractions of coal-tar creosote evaporate from wood. (Cir. 188, U. S. Forest Service.)

that the amount remaining in the treated timber may eventually become so small as to be ineffective in further protecting the wood from decay. This is particularly true of the lighter fractions of coal-tar creosote, as is shown in Fig. 5, which represents the rate at which various fractions of coal-tar creosote and creosote evaporated from sap loblolly pine sticks 6 inches in diameter and 24 inches long impregnated with about 18 pounds

each of oil and later exposed to the atmosphere.[1] in this figure the temperature represents the limits between which the distillates were obtained from the creosote. The permanency of the higher boiling fractions is well shown. Other tests[2] made on timbers subjected to service for 20 or more years also show that the higher boiling constituents are the most permanent.

TABLE 5.—CORROSIVE ACTION OF THE PRESERVATIVE[3]

| Preservatives designated by manufacturer as | Loss in weight (grams) of flange steel after immersion in preservative at 98° C. for | |
|---|---|---|
| | 3 weeks | 4 weeks |
| Coal-tar creosote | 0.0064 | ........ |
| Coal-tar creosote Frac. 1 | 0.0000 | 0.0008 |
| Coal-tar creosote Frac. 2 | 0.0389 | 0.0401 |
| Coal-tar creosote Frac. 3 | 0.0063 | 0.0467 |
| Coal-tar creosote Frac. 4 | 0.0313 | 0.0296 |
| Coal-tar creosote Frac. 5 | 0.0005 | 0.0015 |
| Averarius carbolineum | 0.0807 | 0.0951 |
| Hardwood tar | 8.2629 | 11.2350 |
| Wood creosote (Douglas fir) | 5.0989 | ........ |
| Spirittine | 1.2938 | 1.5029 |
| 1.07 oil | 0.0243 | ........ |
| Timberasphalt | 0.2222 | ........ |
| Copperized oil | 0.0096 | ........ |
| Fuel oil | 0.0012 | 0.0062 |
| Zinc chloride | 1.4636 | ........ |
| Zinc sulphate (*a*) | 0.6050 | ........ |
| Zinc sulphate (*b*) by-product | 1.3809 | ........ |
| B. M. preservative | 3.1660 | 4.1746 |
| Sodium fluoride | 0.1256 | 0.1588 |
| Cresol calcium | 0.0139 | 0.0181 |

(*a*) Equivalent to 2.1 percent zinc-chloride solution.
(*b*) Equivalent to 6.2 percent zinc-chloride solution.

As nearly all wood preserving plants are built of steel cylinders, any preservative which attacks steel cannot, of course, be used in them. This excludes such preservatives as mercuric chloride, copper sulphate, etc., from standard practice. A number of tests were run at the U. S. Forest Products Laboratory to determine the corrosive action on steel of various wood preservatives. A strip of flange steel of the quality specified by the

[1] Circular 188, U. S. Forest Service, by C. H. Teesdale. The Volatilization of Various Fractions of Creosote after Their Injection into Wood.

[2] See circulars 98 and 199, U. S. Forest Service.

[3] "Tests to Determine the Commercial Value of Wood Preservatives," by H. F. Weiss, Eighth International Congress of Applied Chemistry.

American Society for Testing Materials, August 16, 1909, was submerged in the preservative and heated to a constant temperature of about 98° C. The preservative was changed every week for four weeks in the case of oils; with aqueous solutions it was changed every day for one week. The difference in the weight of the steel before and after submersion was taken to indicate its corrosion. All depositions on the surface of the metal were removed as nearly as possible with a rubber "policeman" each time the preservative was changed. At the end of the test, where electrolytic deposition of metal had taken place, the deposited metal was removed by acid and its amount determined by an analysis of the acid solution. The deposited metal thus obtained was added to the loss of iron and this total represented the total corrosion. The corrosive action of the various preservatives tested is shown in Table 5.

The odor of the preservative sometimes influences its use, particularly if the wood is to be placed in dwellings. All inorganic preservatives are practically odorless and hence not objectionable on this account. Many of the organic preservatives, particularly the "creosotes" from wood, coal, and petroleum, have strong odors which are quite offensive. If allowed to air season thoroughly before being placed in position much of the odor can be removed.

It frequently happens that it is desirable to paint wood artificially preserved. This is particularly the case with wood used in dwellings, greenhouses, etc. Creosoted timber cannot be painted satisfactorily with any of the lighter pigments, but practically all of the salts are free from this objection. Two other factors of practical significance in determining the value of a chemical for wood preserving purposes are the effect the preservative has on the strength of the wood treated with it, and the ability of the preservative to penetrate the wood. If the preservative is such as to seriously impair the strength of wood treated with it, it will necessitate the use of larger timbers and hence increase the cost of the structure. Moreover, if the preservative is of such a nature that it cannot be forced into wood, its value is considerably decreased on this account, because it will succeed in only protecting the surface of the wood. Any injury to the surface will therefore result in exposing the untreated interior. Tests to secure data on both these points were conducted at the U. S. Forest Products Laboratory on air-

seasoned hemlock. Approximately 8 pounds of the preservative per cubic foot in the case of oils and 1/2 pound or more of the dry salt in the case of water solutions were forced into the wood by the Bethell process. The wood was then permitted to air season and tested in bending on a 30,000-pound testing machine, the strength of the treated pieces being compared with that of the untreated. In the penetrance tests the preservative was forced into a hole bored into the wood under a constant temperature of 180° F. and pressure of 80 pounds per square inch for 30 minutes when oils were used and 3 minutes for salt solutions. The sticks were then sawed and the depth to which the preservatives entered was measured. The results of both these tests are shown in table 6.

TABLE 6.—PENETRANCE OF THE PRESERVATIVES AND THEIR EFFECT ON THE STRENGTH OF WOOD

| Preservative designed by manufacturer as | Penetration | | | | Average absorption of preservative | Strength in per cent of modulus of rupture of untreated wood | Moisture at test | |
|---|---|---|---|---|---|---|---|---|
| | Rad. and tang. | | Long[1] | | | | | |
| | Max. | Min. | Max. | Min. | | | Untreated | Treated |
| | In. | In. | In. | In. | Lb. per cu. ft. | | % | % |
| Coal-tar creosote | 0.28 | 0.23 | 6.0 | 5.3 | 8.76 | 93 | 6.2 | ..... |
| S.P.F. carbolineum | 0.37 | 0.23 | 6.0 | 5.7+ | 8.83 | ........... | ..... | ..... |
| Avenarius Carbolineum | 0.17 | 0.12 | 6.0 | 5.3+ | 8.08 | 109 | 6.81 | ..... |
| Hardwood tar | 0.03 | 0.03 | 0.92 | 0.50 | 6.50 | 98 | 6.11 | ..... |
| Creosote (Douglas fir) | 0.08 | 0.08 | 3.58 | 2.33 | 2.82 | 107 | 5.8 | ..... |
| 1.07 oil | 0.10 | 0.10 | 6.0 | 3.33 | 9.58 | 108 | 4.52 | ..... |
| Timberasphalt | 0.02 | 0.02 | 0.33 | 0.33 | 5.68 | 106 | 6.68 | ..... |
| Copperized oil | 0.22 | 0.22 | 6.0 | 4.08 | 8.58 | 101 | 5.49 | ..... |
| Zinc chloride | 0.10 | 0.083 | 6.0 | 5.3 | 0.43[2] | 88 | 7.13 | 9.35 |
| Zinc sulphate (by-product) | 0.25 | 0.17 | 6.0 | 4.66 | 1.11 | 82 | 3.88 | 5.77 |
| Zinc sulphate | 0.10 | 0.08 | 6.0 | 4.66 | 0.96 | 89 | 5.14 | 9.6 |
| Creosol calcium | 0.10 | 0.10 | 6.0 | 3.30 | 0.46 | 103 | 5.72 | 6.58 |
| B.M. preservative | 0.13 | 0.10 | 6.0 | 4.6 | 0.50 | 85 | 5.16 | 9.48 |
| Sodium silicate | 0.05 | 0.03 | 0.46 | 0.30 | 0.99 | 82 | 6.42 | 7.38 |
| Sodium fluoride | 0.10 | 0.10 | 6.0 | 5.00 | 0.20 | 85 | 5.82 | 8.7 |

[1] A penetration of 6 inches was the maximum that could be secured. The absorptions here given have no reference to the data on penetrance.

[2] Dry salt.

The effect of the preservative in the wood upon the inflammability of the wood is also an important consideration, particularly in mines, bridges, and dwellings. This effect is described at length in Chapter XVI.

It can be seen from this discussion that many factors aside from cost, ease of transporting, etc., affect the practical value of a

preservative, and that no one preservative possesses all the requirements which will make its use applicable to all conditions. A selection is therefore imperative.

The preservatives which have most conspicuously succeeded in fulfilling the above requirements may be logically grouped into three classes, (1) water-soluble preservatives, (2) crude oils, and (3) creosotes.

**Water-soluble Preservatives.**—While a large number of water-soluble preservatives have been tested, only a few have proven of any practical value. Most of them are either not sufficiently toxic against fungi or form reactions with the wood which tend to destroy the strength of the wood. This latter is particularly the case with iron sulphate and chemicals strongly alkaline. Of the many water-soluble preservatives tested, copper sulphate, mercuric chloride, sodium flouride, and zinc chloride have given best results.

**Copper Sulphate.**—This salt was first put to extensive use by Margary in England about 1837. It was later used by Boucherie in France, where it is still commonly employed in treating timber, particularly poles. It is strongly toxic against wood-destroying fungi. It is readily soluble in water and easily leaches from wood treated with it. The chief objection to its use is its action on iron, the copper being immediately deposited. It cannot, on this account, be used in the standard type of timber-preserving plant. It is comparatively cheap, costing about 5 to 6 cents per pound, and when injected into wood gives good results. It is almost as efficient as zinc chloride, poles treated with it in Germany lasting 11.7 years as compared with similar poles treat ed with zinc chloride which lasted 11.9 years. One desirable quality is the ease with which the preservative can be seen in the wood, as it stains the wood cells a distinct green. The use of this salt is now practically confined to France. The amount of timber treated with it in the United States is insignificant. It is believed, however, to have distinct merit, particularly for the treatment of green posts and poles. (See Boucherie process for further discussion.)

**Mercuric Chloride.**—This is the most toxic wood preservative in use. It was first extensively employed by Kyan in England about 1832. Extremely small quantites of this salt in wood will absolutely kill all wood-destroying fungi. Its toxic limit is even below that of such toxic salts and acids as potassium di-

chromate, silver nitrate, hydrochloric acid, etc. It cannot be safely tested with agar in petri dishes since it unites with the proteid elements of the agar.

Magnin and Sternberg[1] conducted extensive tests with various antiseptics upon the septic micrococcus, with the following results:

| | | |
|---|---|---|
| Corrosive sublimate.......... | 1 part in 40,000 | prevented development. |
| Copper sulphate............ | 1 part in 400 | prevented development. |
| Zinc chloride................ | 1 part in 200 | prevented development. |
| Carbolic acid................ | 1 part in 300 | prevented development. |

Mercuric chloride is much less soluble in water than zinc chloride or copper sulphate. It, unfortunately, severely attacks iron, hence its use is debarred in modern treating plants. Although it is expensive, costing about 70 cents a pound, nevertheless the very small quantity necessary to keep wood sound does not by any means render its use prohibitive. On account of its very poisonous nature, solutions of mercuric chloride must be handled with extreme care or mercurial poisoning will result. This salt is not in extended use at the present time in this country but is employed by a few Kyanizing works in New England. In India and Africa it is reported as giving very good results against the attacks of white ants. Poles treated with it in Germany lasted 13.7 years as against 11.9 years for zinc-treated poles.

**Sodium Fluoride.**—The commercial application of sodium fluoride to the preservative treatment of timber is comparatively recent. It has been tested by Malenkovic in Austria for the past 8 years with apparently excellent results. It is more toxic than zinc chloride (see Table 4) and is not so readily leached from the wood. Its corrosive action on iron is also slight, being less than that for zinc chloride, so that it can be used in modern timber-treating plants. Its cost is also comparatively low, being about 5 to 7 cents per pound. No records are known showing the use of sodium fluoride as a wood preservative in the United States. Extensive experiments, which have thus far yielded very satisfactory results, are now under way at the U. S. Forest Products Laboratory and it is quite likely that this salt may find a large commercial application in this country.

**Zinc Chloride.**—About 20,000,000 pounds of zinc chloride are now used annually in the United States in treating timber—an amount which makes it by far the most extensively used water-

[1] Boulton—The Preservation of Timber, 1885.

soluble salt. It was first employed on an extensive scale by Sir William Burnett in England about 1838 and timber is now treated with it in all the larger European countries. Zinc chloride is very toxic against wood-destroying fungi, offering about the same resistance as coal-tar creosote. Its chief fault is its solubility in water, which property renders it inadvisable to use zinc-treated timbers in wet localities. In localities which are not excessively wet, the zinc chloride will remain in the timber for many years. Numerous cases are on record which show zinc-treated ties have remained durable for 10 or more years, while the untreated failed in 4 to 5 years. It appears from various analyses which have been made that certain amounts of zinc chloride injected into wood combine with the wood forming a compound insoluble in water. Whether or not this combined zinc chloride is toxic has not yet been definitely determined. If it is not, it probably is of little or no value in preserving the wood.

Zinc chloride will also corrode iron, although the extent to which it does this at concentrations used in treating wood is so small as to be of no serious moment. It is customary, however, to figure higher depreciation on zinc-chloride plants than on creosote plants due to its more corrosive nature.

The cost of zinc chloride is small, being about 4 or 5 cents a pound. Moreover, the quality generally produced in this country is of very high grade, far superior to that commonly produced abroad. Zinc chloride is purchased fused in drums of 500- or 1000-pound capacity, or in concentrated (about 50 percent) solution. When in high concentration the solution is basic and will strongly attack wood, reducing it to a pulp. At dilute concentrations the solution is acid.

Owing to its importance as a wood preservative, the following specification for the purchase of zinc chloride is given. It is the one used by the U. S. Forest Products Laboratory. A similar specification is in use by the American Railway Engineering Association.

"The fused zinc chloride must contain at least 94 percent of water-soluble chloride of zinc and it must be slightly basic; that is, contain no free acids. It should be practically free from soluble iron and in no case will it have more than 0.022 percent of this element. It shall not contain more than one-half of 1 percent of other inorganic impurities insoluble in hydrochloric acid."

Although several methods have been suggested for determining the amount of zinc chloride injected into wood, the following is believed to be the most accurate and satisfactory.[1]

The material to be analyzed is first dried in the form of discs or sections and should be a fair average. The discs are then reduced to sawdust and 5 grams are weighed into a 500 c.c. short-neck, round-bottom Jena boiling flask: 50 c.c. of a previously prepared saturated solution of potassium chlorate in concentrated nitric acid is then added in the cold and mixed into it by a vigorous shake. A violent reaction, accompanied by the evolution of considerable heat, immediately takes place but subsides after a few minutes leaving a wine-colored solution in which particles of partly digested wood are floating. When cool, 10 c.c. of concentrated sulphuric acid (sp. gr. 1.8) are added and the solution again shaken. This dissolves all the wood substance. The solution is then boiled. More potassium chlorate-nitric acid solution is added and the solution kept boiling until no further charring occurs on evaporation to sulphuric acid and the solution remains a pale yellow. When cool, it is diluted with 100 c.c. of water; 10 c.c. of dilute nitric, 10 c.c. of 2 percent ferric chloride solution, and 1 gram of citric acid are then added, and the solution again allowed to cool. After cooling it is neutralized with ammonia leaving it slightly ammoniacal. The volume is brought up to 200 c.c. and the temperature to 80° C. at titration. The standard solution of potassium ferrocyanide is then run in from the burette until a drop of the titrated solution when placed in the center of 1 c.c. of the glycerine acetic acid indicator leaves a permanent greenish-blue ring. At this point the titration is complete. Calculations are then made from the analytical data. To calculate the results in pounds of zinc chloride per cubic foot of wood, the specific gravity of the wood must be known to within 0.005. Then multiply this specific gravity to 62.5 and this product by the percentage weight of zinc chloride found by analysis to obtain the amount of zinc chloride per cubic foot of wood.

If knowledge of the actual amount of zinc is not desired, but simply an idea of how deeply it has penetrated, two methods are suggested. One is to cut a section through the stick to be examined and dry it thoroughly in a drying oven heated to 100° C. until all water has been evaporated. The wood will be turned a deep brown wherever the zinc chloride has penetrated. A second method is to dip the freshly cut disc of treated wood for a few seconds in a 1 percent potassium ferrocyanide solution. Remove the excess solution with a blotting paper and redip the disc into a 1 percent solution of uranium acetate. On drying,

[1] Method developed by Bateman, U. S. Forest Products Laboratory.

the untreated portion of the wood will have a dark red color while the treated portion will be much lighter.

**Crude Oils.**—Crude oils are not widely used in treating timber in our country. They rely upon their ability to preserve wood on their tendency to "waterproof" it and thus keep it too dry for wood-destroying fungi. The oils are all practically nontoxic although some of them are slightly poisonous to fungi. In order to "waterproof" the wood it is necessary to force comparatively large quantities of the oil into it. This makes crude-oil treated timber quite heavy and very liable to drip oil, especially if exposed to a hot atmosphere.

Three varieties of "crude oil" are in use, viz., crude oil with a paraffin base, crude oil with an asphaltic base, and residuum, which is a product of petroleum distillation. All these crude oils have a gravity less than water, whereas all creosotes are heavier than water. Crude oils with a paraffin base are found in large quantities in Ohio, Pennsylvania, and other states. They are usually lighter in color and gravity than the oils with an asphaltic base. These latter oils occur in California and part of Texas. Residuum, which is the heavy, rather viscous oil remaining after the distillation of the lighter portions of the crude oil, varies in gravity and viscosity according to the method of manufacture. If too viscous, it cannot be made to penetrate wood. It is best, therefore, when it contains a fairly large percentage of lighter constituents. None of the crude oils penetrate coniferous woods as readily as creosote. This may be due in a large measure to their inability to dissolve the resin in the wood as is done by creosote. The price of crude oils varies from about 2 to 5 cents per gallon. In treating timber with crude oil it is customary to force as much oil into the wood as it is possible to get in—an amount which varies of course with the different woods. If 12 pounds of oil per cubic foot can be retained in the wood, a heavy impregnation has been secured.

**Creosotes.**[1]—Owing to their ability in preserving wood, creosotes will be discussed in detail, as they are the most important preservatives now known.

Much misunderstanding exists as to the meaning of the term "creosote." It is defined by the Standard Dictionary as "a colorless to yellowish oily liquid compound consisting of a mixture

[1] The data given on creosotes is largely taken from Circular 206, U. S Forest Service—"Commercial Creosotes"—by Carlile P. Winslow.

of phenols distilled from wood, and having a smoky odor and burning taste. It is a powerful antiseptic and is used for the preservation of timber, meat, etc.; called also oil of wood-tar and oil of smoke." Allen, in his Commercial Organic Analysis, says: "The name 'kreosot' was first applied by Reichenbach, in 1832, to the characteristic antiseptic principle contained in wood-tar. Carbolic acid was discovered soon after by Runge in coal-tar, and was long confused with the wood-tar principle; and the crude carbolic acid from coal-tar is still known as 'coal-tar creosote.' Somewhat similar products are now obtained from other sources, so that much confusion has arisen. The term 'creosote,' when used without qualification, ought to be understood as signifying the product from wood-tar, but it is better to describe Reichenbach's body as 'wood-tar creosote,' and employ the unqualified word 'creosote' in a generic sense as meaning the mixed phenols and phenoloid bodies obtained from wood-tar, coal-tar, blast-furnace tar, shale oil, bone oil, or other sources."

In its original meaning, therefore, the term "creosote" was applied to a product obtained from wood, and the term is still used thus in pharmacy, and refers to a refined product derived from the destructive distillation of beech or other hardwood. However, with the development of both the wood-preserving and the coal-tar industries, the term "creosote oil," frequently abbreviated to "creosote," gradually came to be applied to the heavy distillates from coal-tar, and the use of the term has become more and more extended until, at the present time, it is commonly used in referring to the distillates heavier than water from any tars or tar-like substances, and is even erroneously used to cover products containing admixtures of undistilled tar or pitch. As a result of this lax use of the word it conveys but little to those conversant with the subject and is confusing to those unfamiliar with commercial practice. More specific terms are evidently needed to properly differentiate between the various creosotes. The most useful classification from the wood preserver's point of view would be one based upon the merits of the various products but lack of sufficient data renders this impossible at this time. The most practical classification at present must be based upon the source and method of production. The following terms and definitions are suggested:

1. **Creosote** is a distillate heavier than water obtained by the distillation of a tar or a tar-like substance.

2. **Coal-tar creosote** is a creosote derived from coal-tar produced by the destructive distillation of coal at a temperature high enough to produce a tar consisting, for the most part, of hydrocarbons of the aromatic series.[1]

3. **Oil-tar creosote**[2] (water-gas tar creosote) is a creosote derived from oil tar. This tar may be obtained from the destructive distillation of petroleum in a gas retort, producing oil-gas as a main product and oil-gas tar as a by-product, or by the cracking of gas oil in the carburetor of a water-gas plant producing carbureted water-gas as a main product, and carbureted water-gas tar as a by-product.

4. **Wood-tar creosote** is a creosote derived from a tar produced by the destructive distillation of wood.

5. **Mixed creosote** is a creosote produced by mixing other material with a given creosote, such as another creosote, pitch, undistilled tar, or petroleum, or it may be secured by the distillation of a mixture of two or more tars on tar-like substances. In view of the similarity between certain mixed creosotes and creosotes obtained by the distillation of coal-tar, produced at temperatures sufficiently low to permit the production of hydrocarbons of the paraffin series, these latter distillates are also classed under this heading.

**Source of Tars.**—Although there are a variety of tars from which creosotes may be produced, the most important commercial ones may be classified as coal-tars, oil-tars, and wood-tars. The sources and general methods of production of these tars are as follows:

*Coal-tars.*—The important coal-tars are derived chiefly from two sources: The destructive distillation of bituminous coal at high temperatures and the combined distillation and combustion of bituminous coal at comparatively low temperatures. The first, which furnishes by far the greater proportion of

[1] Creosote secured from coal-tar produced at sufficiently low temperature to permit the production of hydrocarbons of the paraffine series might also be included under the name of coal-tar creosote, but in view of the paraffin hydrocarbons it is classed in this publication as mixed coal-tar creosote.

[2] Inasmuch as the derivatives of oil-gas tars and water-gas tars contain no phenoloid bodies, the use of the term "creosote" in this connection might, from a purely technical standpoint, be considered erroneous. However, the term is used commercially at the present time in this connection, and a careful consideration of the various definitions used in this publication should prevent any misunderstanding.

the total supply, is produced in the manufacture of coke and gas in by-product retorts and gas-house plants. Bituminous coal is destructively distilled at temperatures varying from 1500° F. to 3000° F., until the charge has been reduced to coke. During the process the ammoniacal liquor and tar are separated from the generated gases by condensation and washing. The tars naturally vary in their properties according to the character of the coal, and of the retorts, and according to the temperatures used. These factors in turn are largely dependent upon which of the two main products, gas or coke, is primarily desired; tar acids, however, are always present in the tars and usually the temperatures are sufficiently high in both cases to produce tars consisting largely of hydrocarbons of the aromatic series.

Coal-tars produced at relatively low temperatures differ from those produced at higher temperatures in the character of their hydrocarbons. Since the temperatures are not high enough to transform all of the hydrocarbons to the aromatic series, the tars contain, to a greater or less extent, hydrocarbons of the paraffin group. Tars secured from blast furnaces using bituminous coal as fuel and from the Mond producer plants, where bituminous coal is used in the manufacture of gas for power purposes, are representative of this group. The production of such tars, however, is not extensive in this country.

*Oil-tars.*—Of the oil tars, that produced in the manufacture of water gas is by far the most important in its relation to the manufacture of creosote. The method of production is, in general, as follows: The "generator" is charged with coke or anthracite coal, which is burned by the aid of an air blast to a cherry red. The hot gases so formed are passed through the "carbureter" and "superheater," which consists of vertical cylindrical chambers filled with a checkerwork of fire brick. After these bricks are heated to the proper temperature the air blast is discontinued and steam is blown into the generator. The gases formed by the contact of the steam with the hot coke or coal pass into the carbureter, into which petroleum "gas oil" is sprayed at the same time. This oil is partially cracked by the high temperature of the fire brick and combines with the gases from the generator to increase their illuminating power; the process of cracking continues through the superheaters. The gas is then passed to the condensers and washers, where tar is con-

densed and collected. This tar differs in its constituents from coal-tar produced in the by-product coke ovens and gas retorts both in the absence of tar acids and in the presence of hydrocarbons of the paraffin series; usually, however, the quantity of paraffin hydrocarbons present is comparatively small.

Some oil-tar also is produced by the destructive distillation of crude petroleum in the manufacture of oil gas. In tars from this source the quantity of paraffin hydrocarbons present is generally much greater than in that produced in the manufacture of carbureted water gas.

*Wood-tars.*—Wood-tar is produced in a manner somewhat similar to that in which by-product coal-tar is formed. Wood is destructively distilled in retorts, and charcoal is produced, together with gas and a liquid distillate which consists largely of pyroligneous acid and a product called crude tar. The tar and acid are separated by settling and by distillation. Wood-tars are quite different from coal-tars and contain, in particular, less of the aromatic hydrocarbons.

**Distillation of Creosote from Tars.**—From any or all of the foregoing tars, either alone or in mixture, creosote may be produced. The general process of manufacture is similar in all cases. The tar is distilled in a metal retort or still and the vapors are condensed and collected. Those distillates which are heavier than water form the true creosotes used in wood preservation. The temperatures at which the creosotes are obtained vary greatly, but generally lie between about 200° and 360° C. The actual temperatures in each case depend largely upon the character of the residue desired. In the United States the manufacture of creosote from coal-tar is generally secondary to the manufacture of soft pitch; and in such cases the maximum temperature during the distillation is comparatively low. In Europe, on the other hand, coal-tar is distilled largely for the production of the coal-tar dyes, and the distillation is carried to higher temperatures. The creosote, therefore, contains a relatively greater amount of the higher boiling constituents than the American product.

As already stated, pitch, undistilled tar, or other similar materials are frequently mixed with a creosote, and while such mixtures are sometimes sold as creosotes, the term is improperly applied except as it relates to the distilled product.

The complexity of the many hydrocarbons and their de-

rivatives which may be produced in the destructive distillation of coal, oil, and wood makes it impossible to state precisely the nature of the various constituents of all creosotes. However, they may be broadly divided into two classes, compounds of the aromatic series and compounds of the paraffin series. The characteristic difference between the two lies in the greater chemical activity of the former. Coal-tar creosote consists almost wholly of aromatic compounds, and the long period of successful use of such creosote has led to the general feeling that these constituents are the more desirable.

The compounds of the aromatic series may be divided into three groups, as follows: (1) "Light oils," which distill below 205° C. and consist largely of phenols and cresols, or tar acids; (2) naphthalenes, which distill between approximately 205°

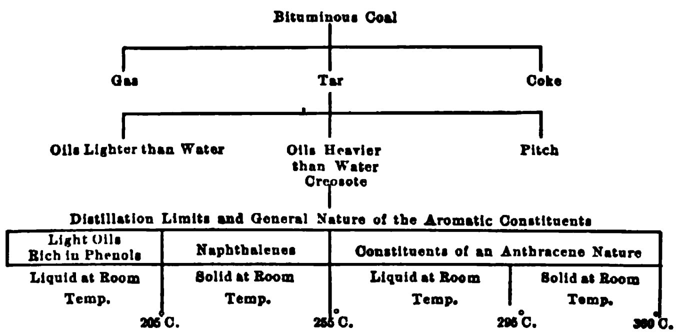


FIG. 6.—Derivation of coal-tar creosote.

and 255° C.; and (3) constituents of an anthracene nature distilling above 255° C., which will be referred to collectively as "anthracenes." Some or all of these are found in most creosotes.

Of these constituents the tar acids possess the highest antiseptic properties; they are, however, soluble in water and are more volatile than the other constituents. The naphthalenes and anthracenes are neither so antiseptic nor so volatile as the tar acids and are practically insoluble in water. There is much discussion as to the relative value of these different constituents, but, largely as a result of experience, the presence of tar acids is believed by many to be essential. While a large proportion of naphthalene is sometimes advocated, particularly for the preservation of piling, a reduction in the quantity of this constituent,

with a corresponding increase in the amount of anthracenes, is believed to increase the value of a creosote for general purposes.

*Coal-tar Creosote.*—Fig. 6[1] shows graphically the derivation and general composition of coal-tar creosote. The relative quantity of tar acids, naphthalenes, and anthracenes will of course vary according to the character of the tar and the temperatures used during its distillation, but generally the tar acids present will not exceed 5 percent, the naphthalenes will comprise from 15 to 50 percent, and the anthracenes will comprise the remainder. As previously defined, it contains practically no paraffin hydrocarbons. The creosote as a whole is antiseptic, insoluble in water, and somewhat volatile; it is sufficiently free from "free carbon," and fluid enough at temperatures used in commercial treating plants, to offer no great resistance to entrance into the wood.

Tests made at the U. S. Forest Products Laboratory show the toxic limit of coal-tar creosote to be between 0.2 and 0.4 per cent. Very small amounts of it will therefore protect wood from decay. In general, the lighter fractions are more toxic than the heavier fractions. They are also far more volatile and when injected into wood by themselves evaporate at a rapid rate (Fig. 30). The heavier constituents of coal-tar creosote are therefore, in addition to being slightly toxic, of direct value in helping to retain in the wood these lighter oils. The permanency of the heavier oils is well illustrated by an analysis made of a pile[2] in actual service in the Gulf of Mexico for 30 years. This pile was cut into three sections, samples from which were then extracted for creosote, with the results shown in Fig. 7.

Numerous similar examples could be cited, all of which show that the lighter fractions of coal-tar creosote are not permanent. While considerable heated discussion has occurred as to their value,[3] it is the author's opinion that these lighter oils have distinct merit in prolonging the life of timber, and if they had been absent entirely from the creosote, it is doubtful if such long periods of service could have been secured.

[1] In Figs. 6 and 8 the term "solid at room temperature" (20° C.) is used in describing the condition of certain of the fractions distilled from creosote, when, at the ordinary temperature of a room, they retained their position in the receiving flask when vigorously shaken.

[2] U. S. Forest Service Circular 199, "Quantity and Quality of Creosote Found in Two Treated Piles after Long Service," by E. Bateman.

[3] "The Preservation of Timber," by S. B. Boulton, 1885.

Coal-tar creosote does not corrode iron to any appreciable degree (see Table 5) and for this reason is admirably adapted for use in the steel cylinders of modern timber treating plants.

When heated, the vapors arising from the oil may attack the skin and cause a very irritating swelling and burning. This effect is not produced on most people, but complaints have been

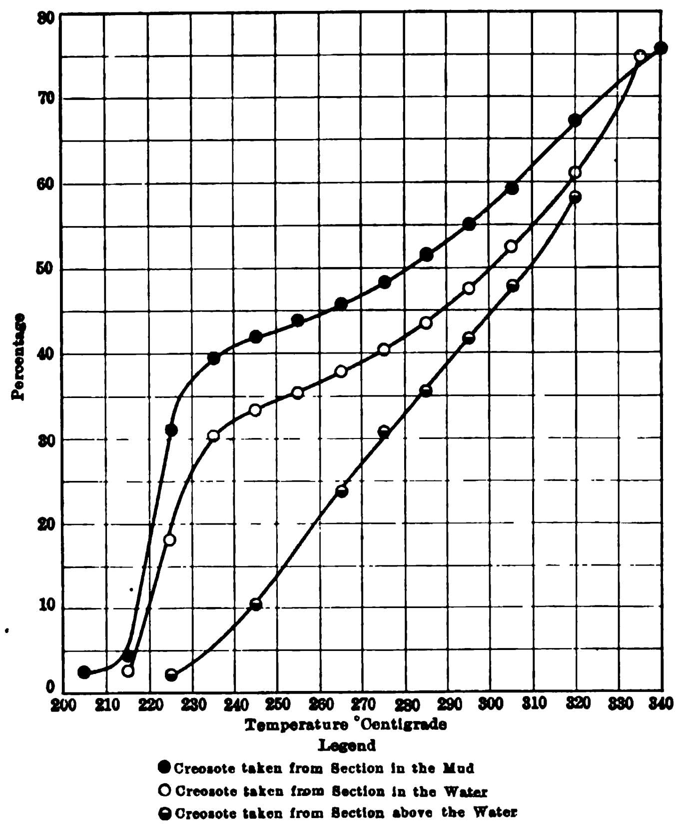


Fig. 7.—Distillation of creosote remaining in a pile after 30 years' service.

made by workers who come in contact with creosoted timber, particularly trackmen, and several law suits have resulted. Even the cold oil may produce such an injury. It is not, however, serious and, with caution in handling the treated timber, even a sensitive person can become immune to any discomfort.

The price of coal-tar creosote varies considerably and for the past few years has been steadily rising. In large quantities the

average price in eastern United States is now about 6 to 9 cents per gallon. In the West, the price is from two to three times this amount, and, in small orders, even more. The sharp demand for the oil, and its present limited production give little hope that the price will lower materially in the immediate future.

Much discussion has occurred concerning the quality of creosote best suited to the treatment of timber. Until recently discussion has resulted in little practical value because the demand for the oil was so great the consumer was glad to receive most any kind he could get. Now, however, several grades of coal-tar creosote can be obtained, but no uniformity exists as yet as to the quality best suited to preserve wood. Most authorities agree that a comparatively heavy grade is better than a light grade. The specifications which are perhaps in most extended use at present in the United States are the ones adopted by the American Railway Engineering Association. They allow three grades of oil, the specifications reading as follows:

"Grade 1 Oil.—The oil used shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal gas tar or coke oven tar and shall be free from any tar, oil or residue obtained from petroleum or any other source, including coal gas tar or coke oven tar; it shall be completely liquid at 38° C. and shall be free from suspended matter; the specific gravity of the oil at 38° C. shall be at least 1.03 when distilled by the common method—that is, using an 8 ounce retort, asbestos covered, with standard thermometer, bulb 1/2 inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give no distillate below 200° C., not more than 5 percent below 210° C., not more than 25 percent below 235° C. and the residue above 355° C. if it exceeds 5 percent in quantity, shall be soft. The oil shall not contain more than 3 percent water."

Grade 2 oil, which is considered "next best," is similar to the "standard" just quoted except for the amount of fractions distilled at varying temperatures, these being "not more than 8 percent below 210° C. and not more than 35 percent below 235° C."

Grade 3, which is poorer than Grade 2, differs from it only in specific gravity and the amount of distillates at various temperatures, these differences being "the specific gravity at 38° C. shall be at least 1.025. Not more than 10 percent of the oil shall distill below 210° C.; not more than 40 percent below 235° C."

The specification in use by the U. S. Forest Service is slightly

more rigid than the above, particularly as regards the method of analyzing the oil (see appendix). Most of the confusion which has occurred concerning the proper kind of creosote to use has come through lack of definite data. Commercial motives and an attempt on the part of certain "experts" to mystify the trade have also added to the complexity of the situation. In all probability, as experience grows the situation will clear and specifications for coal-tar creosote will be drawn depending on the use to which the oil is to be put. Until such data is available the safest course to pursue is to demand a comparatively heavy oil of known purity.

In treating paving blocks a heavy oil is generally used, the idea being that it will stay in the wood and will have a marked waterproofing effect. Thus the "Association for Standardizing Paving Specifications" adopted in 1911 the following grade of oil:

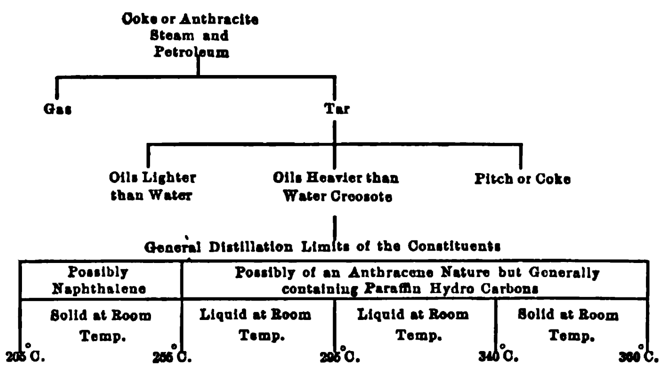


FIG. 8.—Derivation of water-gas-tar creosote.

"The preservative to be used shall be a coal-tar product, free from adulteration of any kind whatever, and shall comply with the following requirements. (1) The specific gravity shall be not less that 1.10 or more than 1.14, at a temperatute of 38° C. (2) Not more than 3½ percent of the oil shall be insoluble by hot continuous extraction with benzol and chloroform. (3) On distillation, which shall be made exactly as described in Bulletin 95 of the American Railway Engineering and Maintenance of Way Association, the distillate shall not exceed 2 percent up to 150° C. and shall be not less than 30 or more than 40 percent up to 315° C."

It is thus apparent that the oil need not be a coal-tar "creosote" and must contain a considerable amount of the heavier con-

stituents in coal-tar in order to have the gravity required. This matter is also discussed in Chapter XIII.

*Water-gas-tar Creosote.*—Of the oil-tar creosotes, that from water-gas tar is practically the only one used for wood preservation. Fig. 8 illustrates its derivation and general composition. This creosote is not more volatile nor soluble in water than coal-tar creosote, contains no "free carbon," and offers no marked resistance to entrance into the wood. In fact, water-gas-tar creosote may be produced which on fractional distillation will display a great similarity to coal-tar creosote. There is a difference, however, in the constituents of the two creosotes, as shown by the difference in certain physical properties of fractions distilled from them at equal temperatures. Furthermore, water-gas-tar creosote is distinctive in the absence of phenols and cresols, and usually in the presence of hydrocarbons of the paraffin group; it is not so antiseptic as coal-tar creosote. Unfortunately, quantities of this oil are mixed with coal-tar creosote, so that it is often impossible in practice to detect its presence. While this oil undoubtedly has considerable merit as a preservative of timber, there is not sufficient precise data available to warrant giving it the confidence which the coal-tar product now enjoys. Careful tests show its toxicity to be about 3 to 4 percent as compared with coal-tar creosote, which has a toxic limit of from 0.2 to 0.4 percent. The most reliable tests known to the author were made by the U. S. Forest Service in treating mine timbers (see Chapter XII) which failed to last as long as similar timbers treated with the coal-tar creosote.

Although it is slightly more corrosive of iron than creosote from coal-tar, its action is so slight that its use in steel cylinders cannot be considered objectionable on this account.

The price of water-gas-tar creosote is seldom quoted but it is generally a cent or two a gallon less than the coal-tar product. There is no doubt but that much of this oil is sold as a coal-tar creosote either alone or in combination and as such commands the same price.

The National Electric Light Association is the only association known to the author which has framed a specification for water-gas-tar creosote to be used in preserving wood. This specification reads as follows:

"It shall have a specific gravity of at least 1.03 and not more than 1.08 at 38° C. There shall be not over 1 percent of residue insoluble in hot

benzol. The oil shall contain not over 2 percent of water. The residue remaining upon sulphonating a portion of the total distillate shall not exceed 5 percent. When 200 grams of the oil are distilled in accordance with the requirements of the specifications for the analysis of water gas tar, dead oil or water-gas-tar creosote and the results calculated to water free oil (*a*) not more than 2 percent of oil shall distill off up to 205° C., (*b*) not more than 10 percent shall distill off up to 235° C., (*c*) not more than 60 percent shall distill off up to 315° C., (*d*) the coke residue shall not exceed 2 percent."

The method of analysis referred to calls for a 300 c.c. side-neck Lunge distilling flask provided with a trap.[1]

*Wood-tar Creosote.*—Of the wood-tar creosotes, that most used in the past has been secured from resinous woods. The derivation

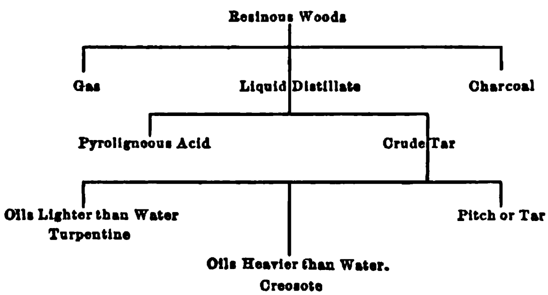


FIG. 9.—Derivation of wood-tar creosote.

of such creosotes is illustrated in Fig. 9. Lack of authentic data prevents even a general statement as to its constituents, but the proportion of tar acids and volatile constituents is generally greater, and of naphthalene and anthracene much less, than in the coal-tar creosotes. Wood-tar creosotes have been used to some extent as wood preservatives for many years. They are, as a rule, not as toxic as coal-tar creosote, their resistance being from about 10 to 50 less than the coal-tar product.

On account of the comparatively large amount of acids which they contain, they corrode iron to a much greater extent than the coal-tar oil and their use in this connection may be considered objectionable. It is but fair to state, however, that this property could be largely overcome if the acids were removed from the oil. Their supply has been so limited and cost so comparatively

[1] Report of Committee on Preservative Treatment of Poles and Cross-Arms," National Electric Light Association, June, 1911.

high that little serious attention has been paid to them except in the manufacture of certain patented products and "stains." The rapid rise in the price of coal-tar creosote and its limited supply have of late attracted considerable attention to the creosotes from wood, hence it is likely their use in preserving wood may become more general in the future.

At present these oils are rarely quoted below 12 cents per gallon even in large quantities, so that the coal-tar product must rise appreciably or the price of the wood-tar oils must fall appreciably before their extensive use will occur. In addition to the tars from resinous woods, there is no good reason why the tars from hard woods cannot be used in manufacturing creosotes. If this is done a larger output will be possible. Just now, no stability in composition is recognized in wood creosotes for preserving timber and hence no general specification for them exists.

*Mixed Coal-tar Creosotes*—A large part of the creosote produced in this country falls into the class of mixed coal-tar creosote. Some is made by the mixture of undistilled coal-tar, or oil-tar, or pitch, with coal-tar creosote; some is produced by the partial distillation and combustion of bituminous coal at comparatively low temperatures; and some is secured through the manufacture of soft pitch when coal-tar and water-gas tar are distilled in admixture. The nature of all mixed coal-tar creosotes cannot be described, because their constituents and relative merits as wood preservatives vary in each case according to the materials used in their production and preparation. Admixtures of undistilled tar or pitch containing free carbon will, however, tend to decrease the penetrance of the creosote, while the admixture of products which contain appreciable amounts of constituents of the paraffin series will doubtless affect in some measure the antiseptic properties of the creosote.

**Paints and Stains.**—Wood which has been painted with ordinary paint (usually a mixture of linseed oil, turpentine, and an inorganic pigment) such as is used in decorating buildings is partially protected from decay because it is rendered partially waterproof. The spores of wood-destroying fungi will not develop readily on the surface of painted wood. To secure best results only air-seasoned wood should be painted, as green wood will be very liable to surface check and expose the untreated interior. Furthermore paint will not adhere as well to green

timber. The layer of paint usually adheres to the surface of the wood and has little or no penetrating power. Moreover, it is generally porous so that certain amounts of water can pass through it. Judged as a preservative of timber, ordinary paint must be considered inefficient and under certain conditions may even do the timber more harm than good, as it tends to equalize moisture in the wood and thus render the interior more favorable to decay.

Stains, on the other hand, penetrate the wood, although as a rule only a slight distance from the surface. In addition, they are generally toxic, so that fungi coming in contact with them will be killed. The composition of stains varies greatly but they commonly have a base of creosote either from coal-, oil-, or wood-tars, to which is added a vegetable or mineral oil to act as a body for the pigment they carry. Best results with stains are secured by applying them only to thoroughly air-dry wood, and whenever possible heating them slightly so that greater penetrating power is obtained. As a rule, stains are better preservatives of wood than paints, and their use, particularly for dwellings, has become very popular of late.

## CHAPTER VII

## THE CONSTRUCTION AND OPERATION OF WOOD PRESERVING PLANTS

In Chapter V we described the relative merits of the open-tank and pressure plants and the general features of their operation dependent upon the particular process selected. In this chapter we will describe the construction of the plants, the effect of the various mechanical manipulations used in them, such as pressure, vacuum, etc., and the cost of building the plants.

**Open-tank Plants.**—Several types of open-tank plants have been constructed. Perhaps the simplest consists in fitting an iron pipe 3 or 4 inches in diameter, blind at one end, into a wooden or iron barrel. A fire is then built around the pipe, which thus heats the oil in the barrel. With wooden barrels trouble is likely to be experienced in maintaining tight joints. If desired 2 barrels can be joined together with one piece of pipe about 8 feet long, and the capacity of the plant thus doubled. Plants of this kind cost less than $5 each. (See Plate VII, Fig. A.)

Another simple method consists in building a fire directly under an iron barrel or tank which is mounted upon stones to form a proper foundation and fire box. More effective results are secured by walling the vessel with brick or stone, thus allowing the heat to pass around the sides as well as the bottom. The draft can also be controlled through a small pipe. (See Plate VII, Fig. B.) Plants of this type cost from $10 to $25 each.

In the types just described, it is difficult to control the intensity of the heat. Better results can be secured if steam is employed, this being passed through coils in the bottom of the tank. Plate VII, Fig. C, shows such an apparatus in which the steam is supplied by a traction engine. In order to cheapen the cost of the tank, sheet or galvanized iron reinforced in a wooden frame may be used in place of heavier metal. If desired a second tank capable of submerging the entire timber in cool

preservative can be used and the capacity of the plant thereby increased. Such a plant including piping costs about $50.

A still more elaborate type consists in building a large rectangular or cylindrical open tank of 1/4-inch or 5/16-inch iron of various dimensions depending upon the size of the material to be treated, and pumping the preservative into it after the wood has been placed in position. This necessitates, in addition to the treating tank, a good force pump, boiler, and auxiliary tanks to hold the preservative. Plants of this kind are well adapted for treating larger quantities of timber than would ordinarily be the case in the plants described above, or heavier timbers such as poles. Their cost varies, of course, with their size, but will range from about $2000 to $6000. One similar to that shown in Plate VI, Fig. C, cost $2500 complete.

All the plants above described are aimed to heat only a portion of the timber, although the entire stock can in some cases be submerged in the preservative should this be considered necessary. Another type of plant for treating comparatively large quantities of small timber such as ties and poles consists in passing them through the hot preservative by means of an endless chain, the length of time they are in the preservative being controlled by the speed of the chain. Such a plant is shown in Plate VII, Fig. D, and has been used with satisfactory results by a traction company in New Jersey. It cost about $1600 and has a capacity of about 1200 ties per 10-hour day. Because of the large surface exposed, only those preservatives which volatilize at high temperatures should be used if most economic results are to be secured. Treatments in plants of this kind are really nothing but prolonged dipping reatments and in this respect differ from the Giussani process, which submerges the wood in a subsequent bath of cool preservative by passing it through a second tank.

**Pressure Plants.**—Considerable quantities of timber are most efficiently handled in pressure plants, which fact accounts for the large number now operating in this and foreign countries. (See Plate VI, Fig. D and Plate VIII, Fig. A.) The essential features in all plants operating on this basis are quite similar, although the details of construction and operation vary through wide limits, these depending upon the opinions and experience of their builders and the class of work the plant is to handle. In general, the following units are characteristic of all pres-

FIG. A.—A post treating plant made of two barrels and an iron pipe. (Forest Service photo.)

FIG. B.—An open tank post treating plant—California. (Forest Service photo.)

(Facing page 90.)

FIG. C.—An open tank post treating plant. Note heat is furnished by steam from threshing engine. Small cylindrical tank is for butt treating in a hot bath; rectangular tank is for a cold bath. (Forest Service photo.)

FIG. D.—Open tank wood preserving plant for ties. The ties are carried through the plant on an endless chain. (Photo through courtesy of the Public Service Corp., Newark, N. J.)

sure plants: (1) A retort house, (2) a pump house or room, (3) a boiler house, (4) a machine shop or room and (5) a yard for storing, loading, and handling the timber. Some plants are also equipped with a sawmill for framing the timber prior to its injection with preservatives. The arrangement of these units in a typical plant is shown in Fig. 10. Variations, of course, occur, especially if the plant is to operate a special process, or only on a given kind of timber. Furthermore, the cylinders may vary in number from 1 to 9 or more, in which case a different arrangement of the units would be made.

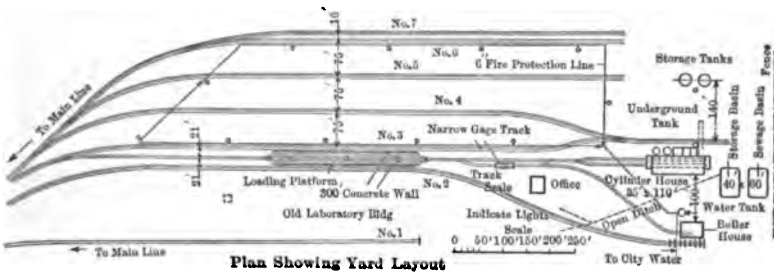


FIG. 10.—Plan showing layout of a typical wood preserving plant. (Drawing through courtesy of the Ry. Eng. and M. of Way.)

**The Retort House.**—The retort house is built primarily to cover and protect the treating cylinders or retorts. In best construction it is made of steel, brick, or re-enforced concrete, although a wooden structure may be used if minimum cost is desired. To guard against loss of preservative due to leaks, or accident, the floor is sometimes made of solid concrete with appropriate drains to a sewer or underground tank, and depressed so that the level of the rails in the retorts will be the same as that of the outside tracks. It is well to so construct the building that a free ventilation can be obtained to carry off the vapors which frequently arise during the operation and to keep the temperature in the house from becoming oppressive to the workmen.

**Retorts (or Cylinders).**—These are invariably built of steel and are cylindrical shells mounted horizontally upon concrete piers. Their diameter varies from about 6 to 9 feet, and length from about 50 to 180 feet. A good size is 7 feet × 132 feet. The 7-foot diameter enables a more economic utilization of space in the cylinder than a smaller diameter and is not too large to

make the handling of the cylinder cars expensive and clumsy. The same reasoning applies to a length of 132 feet or thereabouts. The thickness of the metal in the retorts varies from about 5/16 to 1 inch. Good practice is to use metal of such thickness that working pressures of 150 to 175 pounds can be safely used. In some cases lower pressures of 100 to 125 pounds give satisfaction. The plates of which the retorts are made are riveted with either butt or lap joints. For high pressures the former is the more satisfactory. In order to completely drain the retorts a slight pitch is given them. It is very important to have the retorts mounted upon firm piers, or trouble from buckling is likely to occur. If the plant is built on marshy ground the piers should be made wide at the base and close together or mounted on piles. The retort is perforated to admit pipes, gauges and thermometers, and often has a small dome riveted on the top and in the middle to act as an expansion chamber for the contained air and oil.

**Retort Thermometer.**—The manner of placing the retort thermometer is very important or incorrect readings of temperature will result. The bulb of the thermometer should not be too close to the shell of the retort but should be at least 2 inches from it. The thermometer preferably should be inserted near the middle of the retort and half way up. In order to be sure of the reading a pet cock should be inserted in the thermometer plate and some oil drawn off during the treatment. In addition to the direct-reading thermometer, recording thermometers are also highly desirable, as they give a complete record of temperature during the entire treatment and enable the manager to get an accurate check on his men. Care should be exercised to see that the thermometer is properly calibrated and guarded against the men tampering with it. By ascertaining the temperature at various points in the retort (by means of a maximum and minimum thermometer) the thermometer inserted in the shell can be calibrated to give the average reading in the cylinder.

**Retort Gauges.**—These are inserted in the retort to record the pressures in it, whether above or below atmospheric. They may be inserted at any convenient point in the top of the shell. If direct reading, the gauges should be protected from injury by preservative by means of a water seal or diaphragm. The author's experience with combination pressure and vacuum gauges has not been satisfactory and it is believed separate gauges

FIG. A.—Small wood preserving plant designed by the U. S. Forest Service in co-operation with the Louisiana Creosoting Co. (Forest Service photo.)

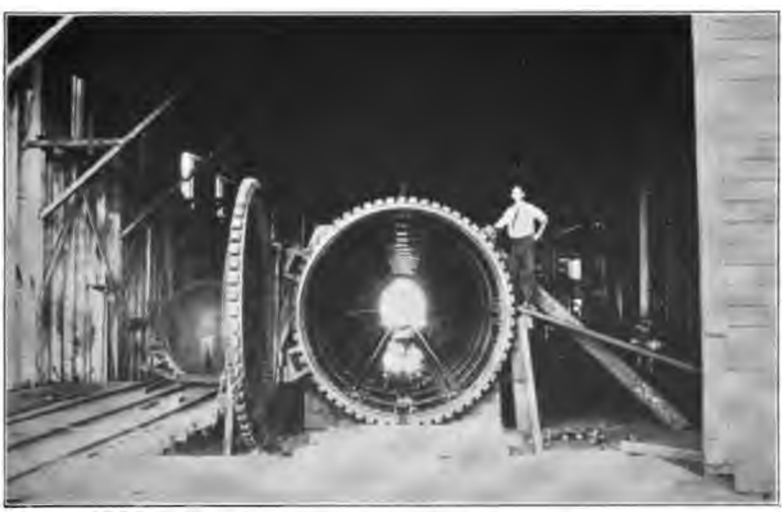

FIG. B.—View through a large treating cylinder. Note guard rails, steam coils and track. International Creosoting and Construction Company.

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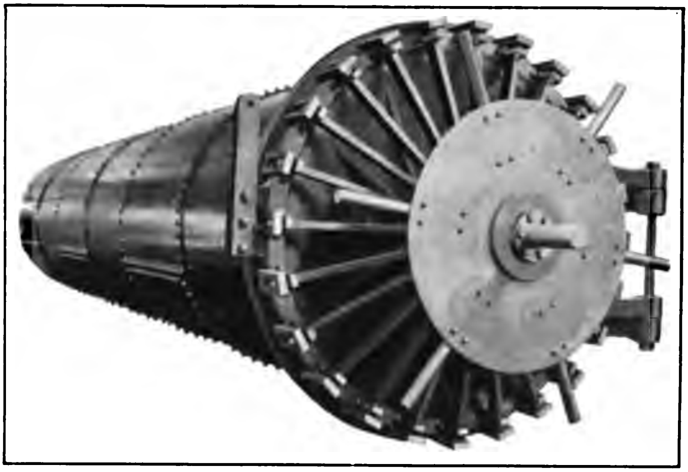

FIG. C.—Spider door with independent sockets. (Photo. through courtesy of the Allis Chalmers Mfg. Co.)

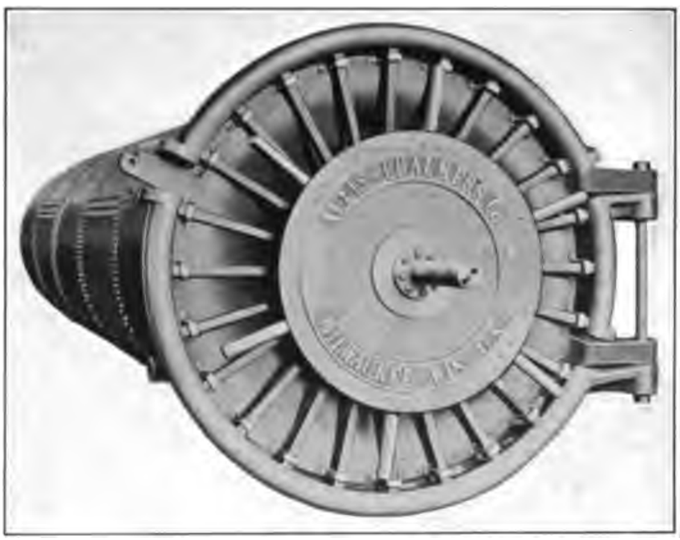

FIG. D.—Spider door with continuous socket support. (Photo through courtesy of the Allis Chalmers Mfg. Co.)

FIG. E.—Construction of a cast steel door. (Photo through courtesy of the Allis Chalmers Mfg. Co.)

give better results. Self-recording gauges are highly recommended.

**Anchors and "Turtles."**—As the temperature of the retort varies considerably, it is necessary to anchor the retort and also allow for its expansion and contraction. Anchorage can best be made at the middle. There are several methods of doing this but embedding a channel or angle iron riveted to the retort in a concrete pier or "tie rods" in two piers prove satisfactory. In some plants the retorts rest in cast-iron saddles or "turtles," which are permitted to slide back and forth over plates embedded in the piers, thus providing for expansion. In other cases the turtles are made of wood. Although steel rollers are sometimes used to permit a freer movement of the "turtles," they are not necessary, as equally satisfactory results can be obtained by simply permitting the expansion and contraction to take place over flat surfaces.

**Retort Coils.**—Steam coils placed in the bottom of the retort, generally over its entire length in order to heat the preservative, are a source of constant expense and trouble unless they are properly laid, as they dilute the preservative with steam and cause leakage of the preservative. (See Plate VIII, Fig. B.) The importance of first-class construction in these coils cannot be overemphasized. A few plants omit the coils but as a general rule they are necessary for best results. Common practice consists in screwing extra heavy 1 1/4 to 2-inch pipes into extra heavy return bends or headers. If this is done only sharp threads should be used and no white lead or any similar material should be permitted in order to makethe joints tight. Two schemes which appear meritorious are to use cast-iron radiators in place of coils, these being coupled in series, or to place one steam pipe inside another, leaving one end free so that it can expand and contract at will. This latter device has been found very satisfactory in practice. In order to protect the coils from possible injury due to derailment and from dirt off the timber, perforated steel plates are frequently laid over them.

**Guard Rails.**—When the cylinder cars loaded with wood are run into the treating retorts, the tendency is for them to float off the track after the perservative is admitted. This is because the buoyant force exerted by the wood is greater than the dead weight of the cars. To overcome the possibility of such trouble, guard rails are generally used. Three types of such guard rails are in

use. In one an angle iron is bolted to the seats riveted to the shell of the cylinder. The car with its load can float partially off the tract equal to the distance between the top of the retort and the top of the iron bale or hoop fastened to the car—a space usually of 1 1/2 to 3 inches. As the preservative is run from the cylinder the car gradually settles into position on the track.

In the other two types a projecting flange is generally riveted to the cylinder car, which slides under the guard rail and thus prevents the car from floating, the only difference in the two types being that in one the projecting flange is riveted on the bottom of the car, while in the other it is on top of the frame.

**Retort Doors.**—These may be fastened on one or both ends of the treating cylinder, depending largely upon the ease with which the timber can be handled in the yard. Retorts with but one door are entirely satisfactory and in the author's opinion are preferable to retorts with doors at both ends. When one door is used the other end of the cylinder is closed with a dished head, thus saving extra expense and often trouble. Retort doors are always fitted to cast-iron or steel rims or "collars" riveted to the shell of the cylinder. These collars are machined with a dove-tailed groove to hold a gasket against which the "tongue" on the door can press. Asbestos rope pounded into this groove and its surface kept well lubricated with graphite and oil makes a very satisfactory packing.

There are several types of doors but they may be classed into two groups, "spider doors" and "bolt doors." The former enable the cylinder to be opened and locked easily and quickly, and for this reason are preferred by some. They are, however, more expensive than bolt doors and are more liable to get out of adjustment and cause leaks. Two kinds of spider doors are generally used. The one shown in Plate VIII, Fig. C, has a center screw and lever nut arranged so that each lever has an independent connection to the frame. The type shown in Plate VIII, Fig. D, is stronger and better constructed and so arranged that the levers are connected to the frame by a continuous-flange ring. Both of these types swing on hinges.

Most treating plants now use some form of bolt door, as the small time of opening and closing is not a very important factor, their cost is low, and their construction simple and efficient. There are several types of bolt doors and several methods of arranging the bolts. A good type is one constructed of solid

cast steel, with independent Tee-bolts fastened to the cylinder and swinging on hinges without a wheel support. This is shown in Plate VIII, Fig. E. Doors are sometimes constructed of a cast-steel rim to which is riveted to a dished-steel plate. Such doors are light in weight but not as strong as those of solid cast steel. (See Plate IX, Figs. A and B.) In some plants the bolts are not mounted to the cylinder but simply rest in slots so they can be removed when not in use. This is the cheapest construction but not as good as where the bolts are fastened and hence always in position ready for use. Bolts with an "eye" in place of a "Tee" are also used, being fastened to a ring which passes through the eye, which is in turn tapped to the collar on the cylinder. This construction is very satisfactory but has an objection in that if one bolt becomes damaged it is necessary to remove all those fastened to the portion of the ring on which it swings in order to make repairs. However, as such damage occurs but seldom and as this construction is cheaper than the independent Tee-bolts, it has very much merit in its favor.

It is very important to properly imbed the curved iron plate or rail upon which the door wheel rolls or the door will either jam or not rest on the wheel. Furthermore, improper foundations will throw the cylinder out of alignment and render the wheel useless.

In order to avoid hinges, doors are sometimes cast without them, as is shown in Plate XI, Fig. C. In this case they are supported on a small derrick or overhead track so they can be swung or run out of the way during the transfer of the cars. Furthermore, they render it unnecessary to entirely remove the nut as is done on some of the bolts near the hinge. However, by proper design this objection can be remedied on the hinged door.

**Retort Lagging.**—Practice in regard to lagging or covering the retorts to prevent heat losses due to radiation varies widely. In northern plants where fuel is high and outside temperature at times very low, several plants have covered their retorts and tanks and secured very good results. The chief objection to covering retorts is the expense and trouble in case of cylinder leaks. It is common practice, however, to lag all steam pipes. Most plants use exhaust steam to heat these various tanks and consider the lagging of the retort unnecessary. It is the author's opinion that lagging is desirable and if properly applied will more

than pay for itself in a few years. Mr. R. W. Yarborough contributed an interesting paper on this subject at the 1911 convention of the Wood Preservers' Association. Mr. Yarborough roughly estimated that about 2,000,000 B.T.Us. were lost per hour in operating a retort 7 feet × 132 feet, which is equivalent to the consumption of about 187 pounds of coal. With coal at $3 per ton, this represents a loss of about 30 cents per hour, or $2.40 per 8-hour day. It costs about $300 to $1200 to cover a 7 foot × 132 foot retort, depending upon the kind of lagging used. Most any fibrous material which is a poor heat conductor can be employed. Cheap coverings can be made according to the following: (1) Sawdust and starch re-enforced with poultry wire, (2) cotton seed hulls, (3) mixture in equal parts of lime, sawdust, and asbestos, (4) sawdust, tar felt, and wood slats.

**The Pump House or Room.**—It is highiy desirable to have the pumping machinery as close to the retorts as possible, as this avoids unnecessary piping and renders the operation more accurate and less troublesome. (See Plate IX, Fig. D.) In best practice this is accomplished by either building the pump house adjoining the retort house or placing the machinery in the retort house and separating it from the retorts by means of a fire wall or partition. Fumes arising from the cylinders are thus confined to the retort house. In the pump house are installed the force pumps for moving the preservatives, vacuum pumps, compressed-air pumps, fire pumps, and at times electrical equipment in case the plant is to operate at night. Gauges for recording temperature, pressure, and vacuum in the retorts are also frequently installed here, as well as the devices for measuring the absorption and consumption of the preservative in the retorts and measuring tanks. The arrangement of this apparatus is one of the most important features in designing a wood preserving plant. It is very essential to use only high-grade machinery and then, if funds permit, provide for duplicate units. Cheap pumps and rigid units always result in troublesome delays and repairs, making good work almost an impossibility. Machinery made by any high-grade concern can, however, be used, its selection being largely a matter of personal taste. Rubber gaskets should not be permitted if they are likely to come in contact with creosote. Likewise, if zinc chloride is to be used the pumping parts should be so constructed that they will not be corroded too rapidly and hence cause the pumps to work unsatisfactorily. It is es-

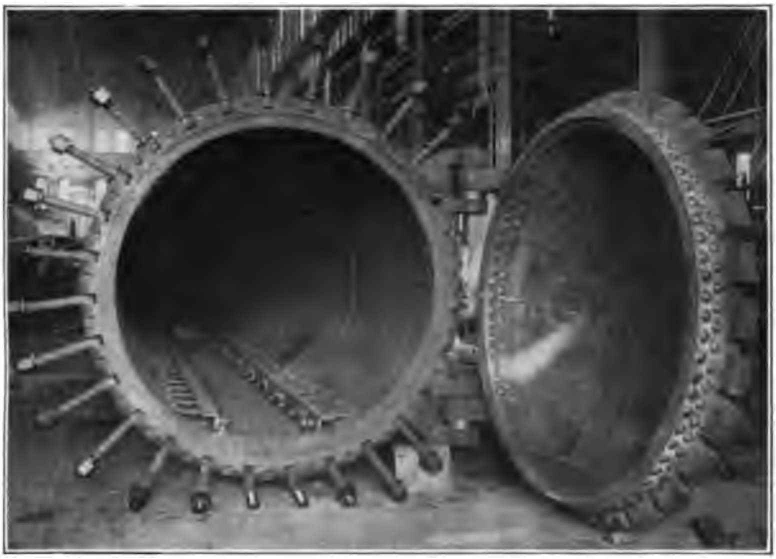

FIG. A.—The construction of the collar and door in a pressure cylinder. Note cylinder track and guard rails. (Photo courtesy of the Allis Chalmers Co.)

FIG. B.—Construction of a door with cast steel rim and dished plate steel head. (Photo. through courtesy of the Allis Chalmers Mfg. Co.)

(Facing page 96.)

FIG. C.—Cylinder doors without hinges. Norfolk Creosoting Company. (Forest Service photo.)

FIG. D.—Pump room C. B. & Q. R. R. treating plant. Note arrangement gauges and control valves.

sential also to have pumps of such design that the packing and working parts can be easily inspected and replaced. Either wet or dry vacuum pumps may be used. If the latter, a surface condenser will be found advantageous. Some plants have done away entirely with force pumps in moving the preservative and applying pressure in the retorts by using compressed air. The author's experience with such equipment has shown it to be highly satisfactory, as it is quick, efficient, and cleans the pipes thoroughly. Care should be taken, however, to prevent an emulsifying of the oil, especially if it contains much water. In fact, it is good policy to so design the plant that the oil can be transferred with a minimum of agitation.

According to Mr. F. J. Angier, the advantages of the air-pumping system over the hydraulic system are:[1]

"Only one tank is required for each retort, that tank serving in the triple capacity of pressure tank, measuring tank, and drain tank.

One air pump is ample for three retorts, while one hydraulic pump is required for each retort.

The maintenance of one air pump is much less than three hydraulic pumps, and is decidedly cleaner. The air pump requires less attention, and lessens the cost of packing, lubricants, valves, valve seats, plungers, etc.

An air pump is a necessity in plants using hydraulic pumps for blowing back solution, unless those plants are equipped with expensive underground receiving tanks. In the latter case an air pump can be dispensed with in lieu of a large oil pump for pumping solution back into the working tank. The underground receiving tank is more expensive in operation than the air pump, and no doubt this is the reason why so few plants are thus equipped.

One air pump can be operated on two or more retorts at the same time without deranging the gauge readings. This is not practicable with hydraulic pumps.

Experience has taught us that it is practically impossible to maintain a steady and constant pressure on a charge of timber with a hydraulic pump, even though it is equipped with relief valves, while with the air pump this is easily accomplished.

The amount of steam required to operate one air pump is not more than would be required to operate three hydraulic pumps, but as the exhaust steam is used for heating purposes, this feature is not so important.

The initial cost of installing the air-pump system is a trifle more than

[1] F. J. Angier, Proceedings American Wood Preservers' Ass'n., 1914.

for the hydraulic pump system, but the maintenance is less, and in the long run air is more economical. The following statement will give some idea of the relative first cost, which may vary one way or the other, depending on local conditions:

Cost of Air-pump System

| | |
|---|---|
| One air pump (capacity 8 cubic feet of compressed air per minute at 175 pounds gauge pressure) | $1200.00 |
| Three pressure-measuring-drain tanks | 2000.00 |
| Piping, valves, etc. (estimated) | 400.00 |
| Total cost of airnydraulic-pump system | $3600.00 |

Cost of Hydraulic Pump System

| | |
|---|---|
| Three hydraulic pumps | $1000.00 |
| Three measuring tanks | 900.00 |
| Two drain tanks | 400.00 |
| One low-pressure air pump | 500.00 |
| Piping, valves, etc. (estimated) | 600.00 |
| Total cost of hydraulic-pump system | $3400.00 |

With hydraulic pumps there is more machinery to care for, more tanks to look after, and more piping and valves to maintain. There is also more work for the engineer, and unless everything is compactly arranged the engineer will require an assistant. With the air pump one man can easily look after the entire operation with greater satisfaction and with better results."

**The Machine Shop or Room.**—This may be an independent building or a room adjoining the retort house, but in either case is a very important element in a pressure preserving plant, especially if the plant is remotely situated. In addition to hammers, chisels, wrenches, etc., it is very desirable to have a good forge, especially for repairing cylinder cars. If the plant is large a lathe will also be found handy. Too much attention cannot be paid to a good pipe-fitting outfit, and only clean, sharp dies should be permitted about the plant.

**The Boiler House.**—As a precaution against fire, the boiler house should be a separate building situated some distance from the treating plant proper. There is nothing novel about the construction of the boiler house. A common mistake, however, is to underestimate boiler capacity, especially where steaming is practised and low temperatures are encountered. A good ratio is about 160 H.P. to a cylinder 7 feet in diameter × 132 feet in length with a working pressure of 125 pounds.

**Yard.**—The yard arrangement is one of the most important features of a wood preserving plant. (See Plate X, Fig. A.) To have the yard designed in a flexible manner so any point can be easily reached without unnecessary distance, to economize in track equipment, to allow proper storage for the timber, and ready means of loading and unloading it is not a problem easy of solution. Many yards are poorly designed, resulting in an unnecessary initial expenditure and excessive operating costs. While the yard layout will vary considerably depending upon the requirements peculiar to each plant, certain general essentials applicable to all yards can be given.

In the first place, the yard should be level, well drained, free from rank vegetation, and if possible covered with cinders. The timber should be piled off the ground at least 8 inches, preferably on creosoted stringers, with sufficient space between the piles to allow a free circulation of air and ready inspection. No decayed wood about the yard should be tolerated.

The track should be well constructed, with good bearing for each tie, properly spaced, in perfect alignment, and even grades. The rail should not be too light but should run 60 pounds or over. To use a very light rail or old rail badly worn or pitted is poor economy. So far as possible the track should be straight and sharp curves avoided. A good working distance between tracks, center to center, is 50 to 70 feet. If the plant is to handle several forms of timber, especially piling, poles, and long dimension stock, the use of 3-rail track for standard and narrow gauge is satisfactory and economical but liable to cause delays. If only ties are to be treated, a narrow gauge in the yard proper is sufficient, standard gauge being used only to tap the main centers of distribution. The number of frogs and crossovers should be kept to a minimum, but should allow sufficient flexibility in moving trams or cars. The use of a transfer table has been suggested by Mr. W. F. Goltra in order to keep the number of switches to a minimum. There appears much merit in this scheme. A yard arrangment for a tie plant is shown in Fig. 10.

**Loading Dock.**—If the plant is to handle large numbers of ties, a loading dock will be found very useful, especially if the plant receives mostly flat cars or gondolas and the ties are loaded by hand. The dimensions of the loading dock will vary, of course, with the size of the plant, but it should have an elevation at least equal to the height of the floor in freight cars. A loading

dock for ties is shown in Plate X, Fig. B. The loading dock enables the foreman to easily keep his workmen in view.

**Methods of Transferring Material in the Yard.**—Practice varies and opinions differ concerning the best method of handling timber in the yard. The tram or cylinder cars are moved in four ways: by cables, dummy engines, electric locomotives, and by horses or mules. For tie plants where the yard arrangement can be simplified, electric locomotives are very satisfactory. For general all-around work the dummy engine is satisfactory, as it is inexpensive, flexible, and efficient. If properly handled it offers no unusual fire risk. When labor is avialable, loading and unloading ties by hand is still best practice, especially when it can be done by piece work. Some plants, however, use the locomotive crane moving a whole buggy load of ties at a time. (See Plate X, Fig. C.) For timbers which are too heavy to be moved by hand the author prefers the locomotive crane to any other system, largely because of its efficiency and flexibility. Stationary derricks operated by cables are also satisfactory for heavy timbers, but have not the radius of action of the locomotive crane. Traveling cranes are also used by some plants but like the derrick are limited in their territory. Furthermore, unless the structures on which they run are properly braced and mounted on solid foundations, they will get out of alignment and cause trouble. In a few treating plants small canals filled with water run through the yard. The heavy timbers are rolled off skids into these canals and floated to the retort house, where they are placed on the cylinder cars by a traveling crane. (See Plate X, Fig. D.) A few coast plants store their heavy timbers as rafts in water—a method which of courseprecludes any air seasoning.

**Cylinder Cars.**—These are also referred to as tram cars, bolster cars, retort cars, and "buggies." Three general types are generally recognized: (1) a tie car of rigid construction throughout, (2) a swivel or bolster car which has a pivot bearing to allow for long timbers in rounding curve, and (3) a block car for holding paving blocks. Two of these types are shown in Plate XI, Fig. A, and Fig. B. There are two essential features in the proper building of all types, which are often sadly neglected, viz., a heavy, substantial construction and a maximum holding capacity. On account of the severe usage to which the cars are put, they should be made very strong or they will soon be broken or bent and consigned either to the repair shop or scrap heap. Especial attention should be given

FIG. A.—Chicago and Northwestern Tie Treating Plant, Escanaba, Mich. (Photo through courtesy C. & N. W. R. R..)

FIG. B.—Tie treating plant of the Pennsylvania R. R. Note concrete loading dock with empty cylinder cars on top, also manner of unloading and piling ties for air seasoning. (Photo through courtesy of the P. R. R.)

(*Facing page* 100.)

FIG. C.—Unloading treated ties from cylinder buggies into gondolas with a locomotive crane. Port Reading Creosoting Co. (Forest Service photo.)

FIG. D.—Overhead electric crane for loading timber into cylinder cars. Gulfport Creosoting Co., Gulfport, Miss.

to properly reenforcing the curved arms so they will not bend and jam in the cylinder. The frame work should also be set low or the treating capacity of the plant will be greatly decreased. A solid iron hoop or "bail" is preferred to chains, in order to hold the timbers on the car, and no jamming or pounding of the bails should be tolerated. It is almost universal practice to build the cars without couplers, the idea being to save expense, time and space in the cylinder. Hence the cars must always be pushed and never pulled. Some plants broke away from this practice and used couplers on their cars so they could be pulled as well as pushed—a scheme which has been prohibited in certain states because of danger to workmen. Block cars can be made out of tie cars by simply placing on the tie car a perforated sheet-iron basket with hinged doors. In some cases the cars are built purposely for handling blocks and so designed that they can be emptied by lifting them bodily with a locomotive crane and turning them upside down.

A good feature in the design of cylinder cars is to have loose wheels of heavy construction fitted with roller bearings and a fairly wide tread.

**Measuring, Mixing, Working, and Storage Tanks.**—A measuring tank is one used for measuring the absorption of preservative forced into the wood. It is invariably constructed of steel. It is considered good practice to have the diameter of these tanks as small as possible in order to allow for an accurate reading of the preservative and to have them accurately calibrated. Furthermore, they should be placed as close to the retorts as proper design will permit. Some engineers have carried this idea as far as to place them directly over the retorts. The size of the measuring tanks in relation to the size of the retort varies greatly in practice. In some plants the volume of the measuring tanks is 1 1/2 times the volume of the cylinder, in others it is less than half the volume of the cylinder. In most plants these tanks are built to withstand the pressure due to only the head of the preservative, and are elevated upon stationary platforms so that the preservative can flow from them into the retorts by gravity. In a few plants, using compressed air, the measuring tanks are mounted on the ground and built to withstand a working pressure equal to that of the retorts. Another design mounts the measuring tanks upon scales so that as the preservative is pumped out of them through flexible connections the amount

of preservative forced into the retorts can be read directly. All float gauges are in this case done away with. The author prefers the two latter designs of constructing tanks of this kind.

Mixing tanks are used for making solutions of zinc chloride. A substantial construction is to use wood lined with lead. Concentrated solutions of zinc chloride are basic and will attack wood. If tar is mixed with creosote the tanks in which this is done are also sometimes called "mixing tanks" and are generally built of steel.

Working tanks are intermediate in size to measuring and storage tanks and are in common use. They are not used to measure absorption but to aid the measuring tanks in filling the retorts with preservative. In other words, after the wood has been placed in the retorts and the doors locked, the preservative is run from the working tank until the retort is filled, after which the preservative is drawn from the measuring tank. Working tanks are usually built of steel and elevated so that the preservative can run from them into the retorts by gravity. If zinc chloride is used, the tanks are frequently built of wood, as weak solutions of zinc chloride will attack steel. In some plants working tanks are not used, in which case the measuring tanks are made with larger capacity. Working tanks may have from about 1 to 3 times the capacity of the retorts.

Storage tanks, as the name implies, are used to store the preservative. There is no agreement as to size, this depending upon the requirements of each plant. They are generally located some distance from the plant proper as a matter of safety. It is well to have the storage tanks at least sufficiently large to allow for a month's supply when operating at full capacity. On account of their large size, storage tanks are frequently built without a roof, evaporation of oil being retarded by means of a water seal. Generally the measuring and working tanks are covered.

Some plants are equipped with receiving tanks, which are buried below ground so that the excess preservative in the retorts can be drained into them, after which it is pumped back into the working or measuring tanks. This enables a quick emptying of the cylinders. When the excess preservative is pumped or blown back from the cylinders, these tanks are unnecessary.

Because creosote congeals at low temperatures, all of the tanks described are generally fitted with steam coils through which exhaust or live steam may be passed. Traps should be

PLATE XI

FIG. A.—Bolster Car. Used for long timbers. (Photo through courtesy of the Allis Chalmers Mfg. Co.)

FIG. B.—A tie car. (Photo through courtesy of the Allis Chalmers Mfg. Co.)

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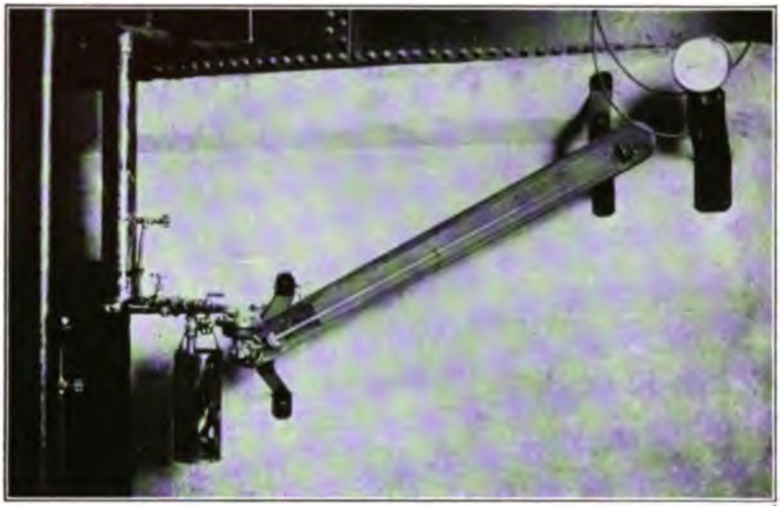

FIG. C.—Mercury gauge for measuring the preservative in the measuring tank. Baltimore & Ohio R. R. Tie Plant. (Photo through courtesy of the B. &O. R. R.)

FIG. D.—Wood Block treating plant of the Chicago Creosoting Co., Terre Haute, Ind. Note vertical cylinders. (Photo through courtesy of the Chicago Creosoting Co.)

coupled to the exhaust ends of all these coils. Air is at times passed through the storage tanks in order to keep the composition of the preservative uniform.

**Gauges and Scales.**—Many plants are still careless in their methods of measuring absorptions of preservative. Of course, if the plant is doing its own work, as in most railroad plants, accurate measurements of absorption are not as essential as in commercial plants treating on contract. However, in either case, correct determinations are at least desirable. Several methods of measuring absorption are in practice. The most common is to have a float and tell-tale sliding on a vertical scale board, the two connected by a chain or fine piano or annealed wire which runs over pulleys. If the float, tell-tale, and pulleys are large, operating with little friction, the scale board accurately calibrated, the chain or wire protected from the wind, and the preservative, if an oil, corrected for temperature expansion, this method is simple and gives satisfactory results. Care should be taken to agitate the preservative as little as possible in pumping or blowing back.

When compressed air is forced into the top of the measuring tank the total absorption may be determined by gauge glasses or pet cock fastened to it, and a check on the total amount made after the excess preservative has been pumped or blown back from the retort.

If the measuring tank is mounted on a scale, the absorption may be read directly from the scale beam in pounds. This renders corrections for temperature expansion unnecessary in the measuring tank. Another excellent device is to use a mercury column set at an angle to the desired degree of sensitiveness. (See Plate XI, Fig. C.) Readings in pounds can thus be directly and accurately obtained. Care should be taken to keep the oil in the gauge pipes liquid and free from air. A very good check on the methods just described is to weigh the timber on track scales before it goes into the retorts and immediately after it comes out. This, doubtless, is the most accurate way of determining absorption. It cannot be used, however, if the timber is steamed or boiled in oil while in the retort, as such treatments change the weight of the untreated wood. It is by no means easy to measure accurately the amount of preservative the charge of wood is absorbing, especially during treatment, and this is largely a matter dependent upon the skill of the operator. A very im-

portant aid in gauging absorption is to have accurate thermometers in all tanks used during the treatment.

**Piping.**—The importance of using sharp, clean threads in making pipe connections has already been emphasized. Too much emphasis cannot be laid upon this detail. It is also highly desirable to make all pipe lines—especially those for transferring oil—as short as possible, and to provide a system whereby then can be completely drained, with a sump if necessary. Otherwise, trouble may be experienced with the oil congealing in the pipes. Another essential is to use only high-grade gate valves with replaceable wearing parts in all lines for transferring liquid, and to pack these with material not attacked by the preservative. A precaution against leaks or breakage is to have duplicate valves in all important lines. As considerable dirt, pieces, of bark, etc., fall from the timber, all lines transferring preservative from the retorts should be protected with perforated plates or screens. A "mud drum" placed below the retorts is a good precaution. If these safeguards are not taken, the valves run a decided risk of being either damaged or destroyed.

**Shower Baths.**—Under best operating conditions a wood-preserving plant is none too clean a place for workmen. Those companies which have installed locker rooms and shower baths for their men have found their investment a paying one. Since these can be installed at small expense, they are recommended.

**Inspector's Laboratory.**—Too frequently an inspector's or chemical laboratory is either omitted entirely, or when an attempt is made to furnish one, it is a good place to avoid. This is bad business policy, as the most progressive companies have discovered. While, of course, an elaborate outfit is not necessary, the place should be clean, well lighted, comfortable, and equipped with proper apparatus. In brief, the inspector's laboratory should contain a detailed map of the plant, showing all valves and pipe lines, with tables giving the dimensions of all essential plant units. It should have tools, such as rules, tapes, a brace and bit, saws, and hatchets, for studying the penetrations, and standard tables for ready reference; apparatus and chemicals for analyzing the preservative, including retorts, flasks, beakers, pipettes, hydrometers, etc., and a chemical balance. While not absolutely necessary, a drying oven for studying moisture in wood and a refractometer for studying oils will also be found helpful. Samples of wood properly iden-

tified as to kinds and showing proper treatment will also be found valuable. Some companies have not only equipped their plants with such laboratories, but have furnished a small experimental plant. Unfortunately, the press of daily routine almost invariably prevents the operators from carrying on experiments in them.

**Fire Protection.**—The best fire protection lies in proper prevention through wise design and efficient operation. Under such conditions danger from fire is very slight. However, as added precaution and to meet underwriters' requirements, a good fire pump is highly desirable. In addition, the water storage tank can be drawn upon. Fire hydrants should also be installed in the yard and properly maintained. Some plants leave fire lanes between the piles of timber 30 or more feet in width. Boxes of sand protected against rain and equipped with shovels are an excellent safety factor, as well as hand chemical extinguishers hung at vital points in the plant.

**Lighting Equipment.**—As the plants are often called upon to run at night, the dynamos should be sufficiently powerful to not only light the plant proper but also arc lights in the yard. As a general rule, however, loading and unloading of material should be confined as much as possible to the daytime, leaving only the treatments for night work.

**Sawmill and Block Equipment.**—Several wood-preserving plants in the United States are equipped with small sawmills to frame their timbers before treatment. The framing of such timbers before the preservative is injected is good practice, as it insures a protection to the wood over its entire surface. In fact, ideal practice would be to have the timber framed to the exact dimensions required so that no cutting or boring would be required after it has been treated. There is nothing novel about the construction or operation of these sawmills. They can be located at any convenient place in the yard and, as a matter of safety, some distance from the treating plant.

The manufacture of wood blocks is almost invariably done in connection with the treating plant, the timber being received in planks and sawed into the various sizes of blocks required. The planks are carried by chain conveyors to the saws, which are spaced so as to cut them into the desired depth of block. In some plants the saws are all arranged on the same axis and the blocks all cut at one time. In others the planks are first

cut into smaller planks, which are in turn cut into blocks, it being claimed that this economizes in wood consumption, as knots, etc., can be trimmed with least waste. The blocks then fall from the saws onto a conveyor, which either carries them to a bin, or, preferably, direct to the cylinder cars, into which they are dumped by gravity. A good design is to have the cylinder cars on a track paralleling the block conveyor. As the blocks are carried along the conveyor they can be inspected and all defective blocks removed. By having small swinging gates along the side of the conveyor, the operator can open one, using it to deflect the blocks into the cylinder car below, and after this has been filled, close the gate and open the next one situated further on, thus deflecting the blocks into the second car, and so on until the entire charge is filled. This method works very efficiently and minimizes labor. The rate at which the blocks can be manufactured varies, of course, upon the size and speed of the machine and depth to which the blocks are cut. A good machine, however, should turn out 200 square yards of 4-inch. blocks per hour.

The Chicago Creosoting Company has recently taken out patents on a new type of plant for treating paving blocks which does away entirely with cylinder cars and enables a decreased cost in operation. Their cylinders, which are 11 feet in diameter and 14 feet high, are built vertical, the blocks being carried on a conveyor and dumped automatically into the cylinder. The treatment is then conducted in the usual manner, after which the door in the bottom of the retort is opened and the blocks fall directly into cars for shipment. (See Plate XI, Fig. D.)

**Tie-boring and Adzing Machines.**—At present few treating plants consider tie-boring and adzing machines as a fixed part of their equipment. There is no doubt but what such machines are a desirable asset to any plant which is treating large quantities of ties, and that they will be viewed with increasing favor because of the excellent results secured from them. These machines at present are generally mounted upon a portable platform such as an improvised box car and are driven by a gas engine. (See Plate XII, Fig. A–Plate XII, Fig. B.) The rough ties are placed on a conveyor which automatically passes the ties through the machine, where they are adzed and bored. Other attachments are sometimes used, such as a device for trimming the ties to exact length, and a die or punch which brands them on the ends, this giving the date, kind of treatment or species of wood. The ties

FIG. A.—Ties entering boring and adzing machine. (Photo through courtesy of the Greenlee Bros. Co.)

FIG. B.—Ties adzed and bored being piled on the cylinder cars ready for treatment. (Photo through courtesy of the Greenslee Bros. Co.)

(Facing page 106.)

PLATE XII

FIG. C.—Section through an oak tie showing a cut and screw spike driven in place. Note comparative distortion of wood fibers. (Photo through courtesy of the Spencer-Otis Co.)

then pass down a conveyor on the opposite side of the car, where they are piled either in stacks or directly upon cylinder cars for treatment. The capacity of these machines varies but averages about 3000 ties per 10-hour day. The advantages of such treatment are given in greater detail in Chapter VIII. The total cost of adzing and boring ties varies from about 1 1/4 to 2 cents each.

**The Operation of Pressure Plants.**—The operation of pressure wood-preserving plants varies widely, depending upon local conditions, the opinion of the engineer in charge, and the processes used. The latter have been described in detail in Chapter V but we will discuss here the effect of the various manipulations more or less common to all plants. Unfortunately, the amount of exact data available is very meager, and results are often secured without knowing why; hence the success or failure of a treatment depends very largely upon the experience of the operator.

**The Effect of Vacuum.**—A vacuum may be drawn in the treating cylinder before the preservative is admitted, or after the preservative has been forced into the timber, or both before and after. When drawn before admission of preservative, it is referred to as a "preliminary vacuum." If drawn after injection it is called a "final vacuum."

As stated in Chapter IV, a preliminary vacuum drawn immediately after the timber has been steamed helps to dry the timber. The reduced pressure in the cylinder lowers the boiling point of water and hence hastens the rate with which it evaporates. When a preliminary vacuum is drawn on air-seasoned wood it also tends to slightly dry the wood and remove an appreciable amount of air from it. If, now, the preservative is admitted to the cylinder without breaking the vacuum, the speed with which the cylinder fills is increased. Furthermore, the preservative can usually be forced into the wood in a shorter time and with less difficulty. But the most noticeable effect is the manner in which the preservative is held in the wood after the pressure is released (Fig. 11). It will be noticed that only a comparatively small amount of it rebounds or drips from the timber. The absence of large amounts of air in the wood cells is undoubtedly the cause of this, since on the release of pressure there is not sufficient expansion of this air in the wood to force out much of the preserving fluid. In order to leave the greatest amount of preservative in a given stick of timber, therefore, a preliminary vacuum should be used. This fact is of prime importance in

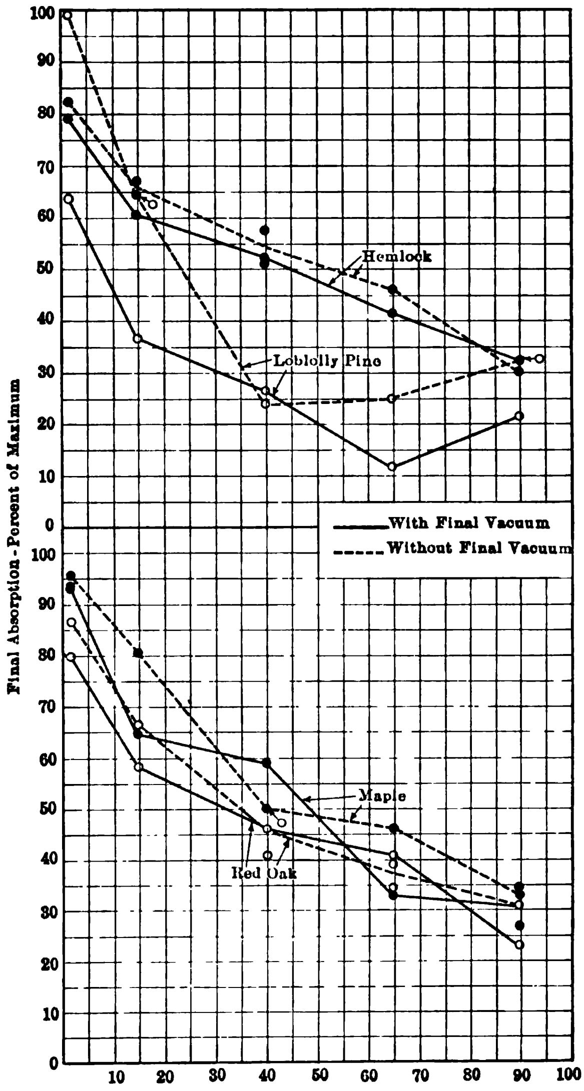


FIG. 11.—Showing the effect of air in ties upon the amount of creosote retained in them.

treating timbers which are resistant to absorption or when large absorptions are desired. The greater the intensity of the vacuum, the better will be this result, and, if possible, at least 26 inches should be obtained. The length of time the vacuum should be held depends chiefly upon the kind and size of timber being treated. Porous woods like maple and red oak require a shorter vacuum period than resistant woods like hemlock and tamarack. Small size timbers require a shorter vacuum period than large size. Exact periods for all species and sizes of wood are not definitely known. Some attempts to secure data on the rate at which a vacuum can be drawn on the interior of air-seasoned ties were made at the U. S. Forest Products Laboratory by boring a hole to the center of the tie and inserting a small pipe connected with a vacuum gauge fastened to the shell of the cylinder, and thus drawing a vacuum in the cylinder. It was found that in the porous woods like red oak the vacuum on the inside approached that on the outside much more rapidly than in the more resistant woods like hemlock. Of course, it is not necessary to secure as great a vacuum in the center of timber as in the outside, because the preservative can rarely be forced to the center, especially in large-sized sticks, but the closer this can be obtained, the more beneficial will be the results.

To sum up the effect of a preliminary vacuum:

1. More preservative is absorbed during the filling of the cylinder than when no preliminary vacuum is used (Fig. 12). This is especially true in porous woods like loblolly pine.
2. It reduces the length of time pressure must be held in the cylinder in order to secure the desired absorption. This difference is apparently very slight in woods of moderate porosity like maple, but considerable in porous or resistant woods like loblolly pine or hemlock (Fig. 12).
3. It reduces to a minimum the rebound or "kickback" of the preservative on the release of pressure in the cylinder (Fig. 12).
4. It reduces to a minimum the amount of drip (Fig. 12).
5. It enables very heavy absorptions to be more easily obtained.
6. It tends to produce very unequal penetrations and absorptions if only small amounts of preservative are forced into wood and hence should not be used in such cases.

A final vacuum produces the opposite effect of a preliminary vacuum in that it tends to remove the preservative from the wood. It is greatly aided in doing this if air is left in the wood or if the wood is treated with compressed air before the preservative is admitted. The vacuum causes this air to expand and force out

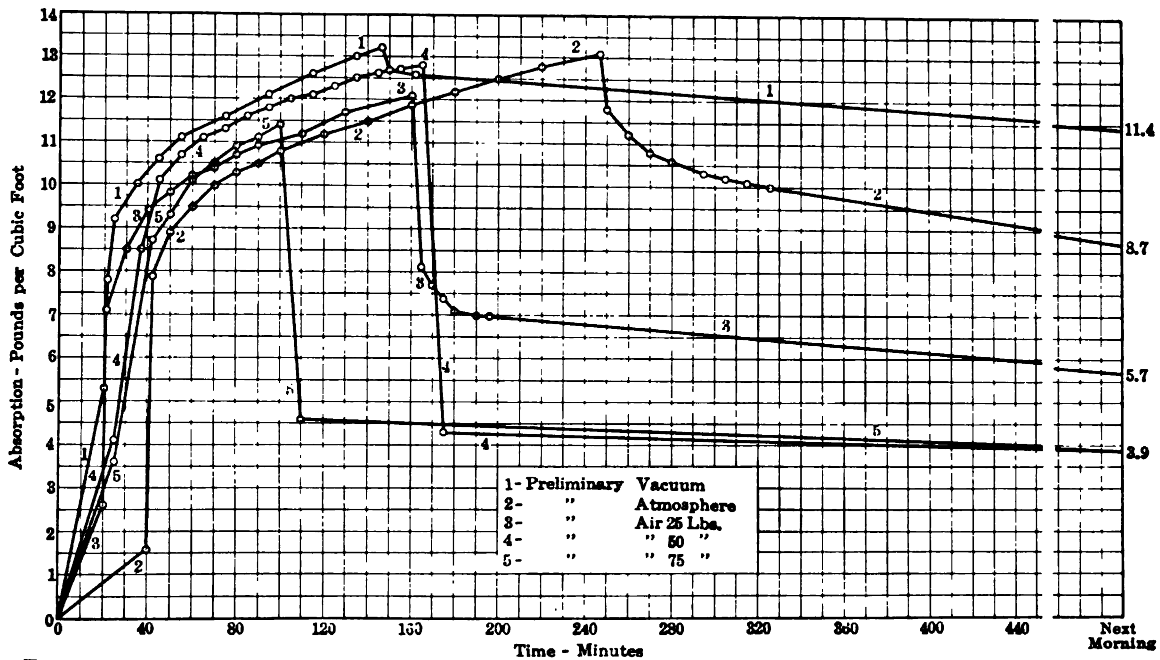


FIG. 12.—Absorption-time curves in creosoting red oak ties by the pressure processes. Note the effect of air in the ties upon the time required to secure the desired absorption, the "kickback" on release of pressure, and the rate and amount of drip. No final vacuum was drawn in these tests.

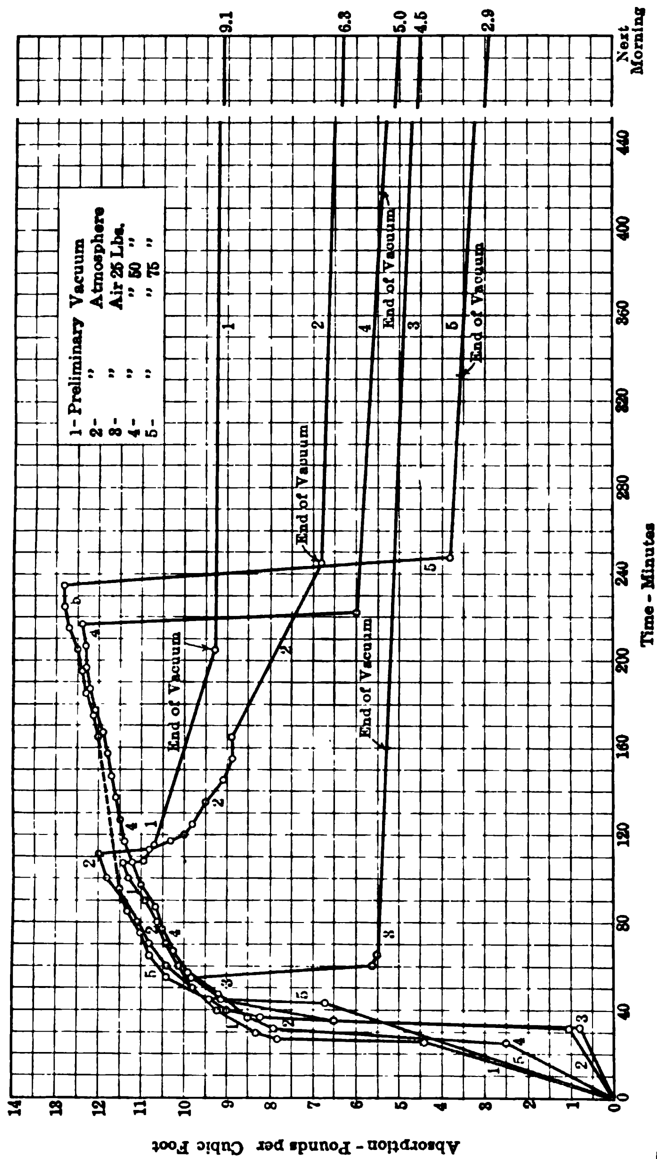


FIG. 13.—Absorption-time curves in creosoting red-oak ties by the pressure processes. Same as shown in Fig. 12, except that a final vacuum was drawn in these tests. Compare total recovery with that shown in Fig. 12.

the preservative. A final vacuum is drawn either to dry the timber and thus reduce loss of preservative through drip, or to withdraw a portion of the preservative (see description of "empty-cell" processes), or to do both. In the tests referred to above, a final vacuum was drawn on some of the ties and its effect in recovering creosote is shown in Figs. 13 and 14. In these tests the amount of preservative recovered was about 10 percent more than when no final vacuum was drawn, being greatest in woods easily treated and least in those which are resistant to injection. It should be noted that if a preliminary vacuum is used in connection with a final vacuum, a very small recovery of oil is secured, hence in heavy treatments both may be used to advantage.

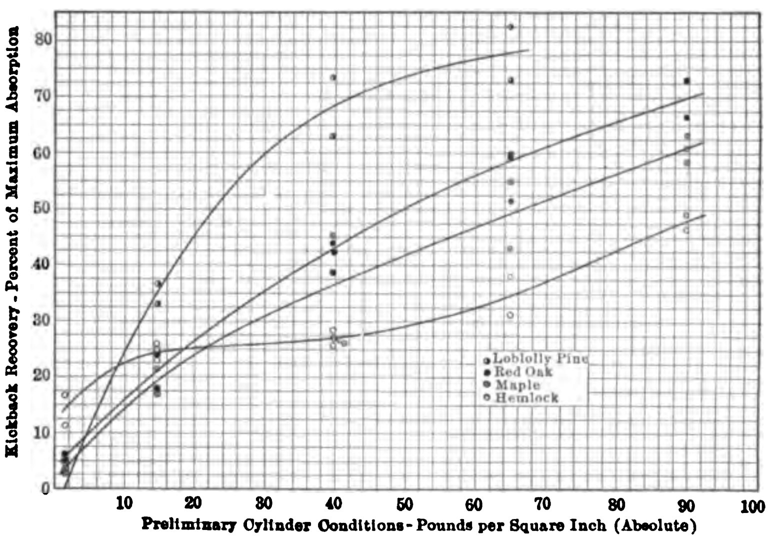


Fig. 14.—Showing the effect of air in ties upon the "kickback" with creosote.

To sum up the effect of a final vacuum:

1. It dries the ties and hence reduces drip (Fig. 13).
2. It removes some of the preservative injected into the ties, although this, *in itself*, is apparently not great, but may be appreciable if used in connection with a preliminary or atmospheric air pressure (Figs. 13 and 15).

**The Effect of Air Pressure**.—Air pressure is used either before or after the preservative is forced into the wood; hence, as with the vacuum, we have "preliminary" and "final" air pressures.

Preliminary air pressures are used to force a portion of the preservative out of the wood and hence give an "empty cell"

treatment. (See Rueping Process.) As would be expected, it can be forced more easily into porous than nonporous woods. If a preservative is forced into wood filled with compressed air

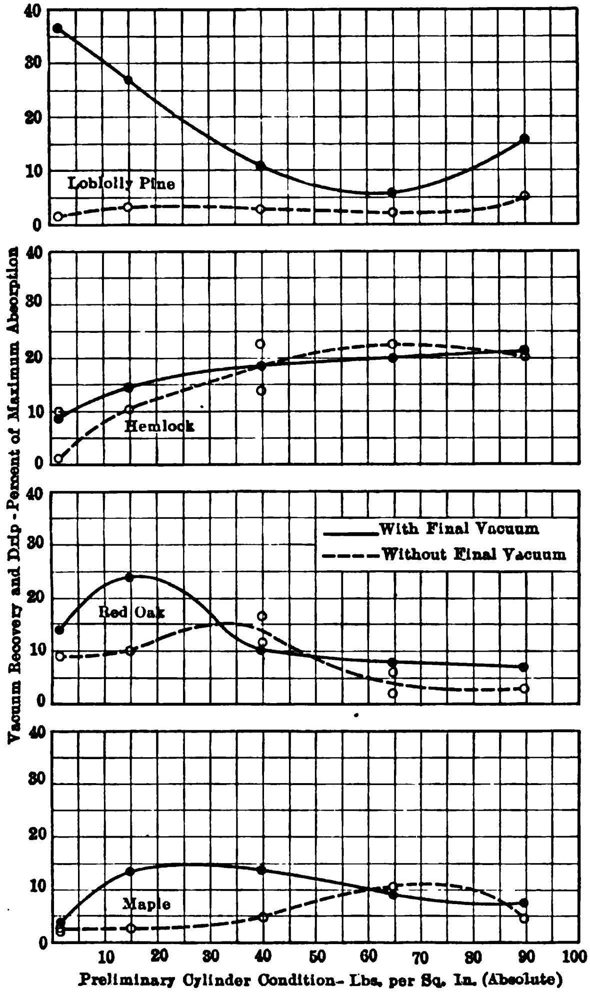


FIG. 15.—Showing the effect of air in ties upon the amount of creosote recovered by a final vacuum and drip.

and the pressure on the preservative is then released, the air in the wood will expand and force out a part of the preservative. Some data on the amount thus forced out is shown in Figs. 12 and 13. It will be noted that the amount of air forced out varies,

up to a certain ratio, with the amount of air forced into the wood, and that a final vacuum increases this amount (Fig. 15). It has been noticed, however, that it takes the compressed air in wood

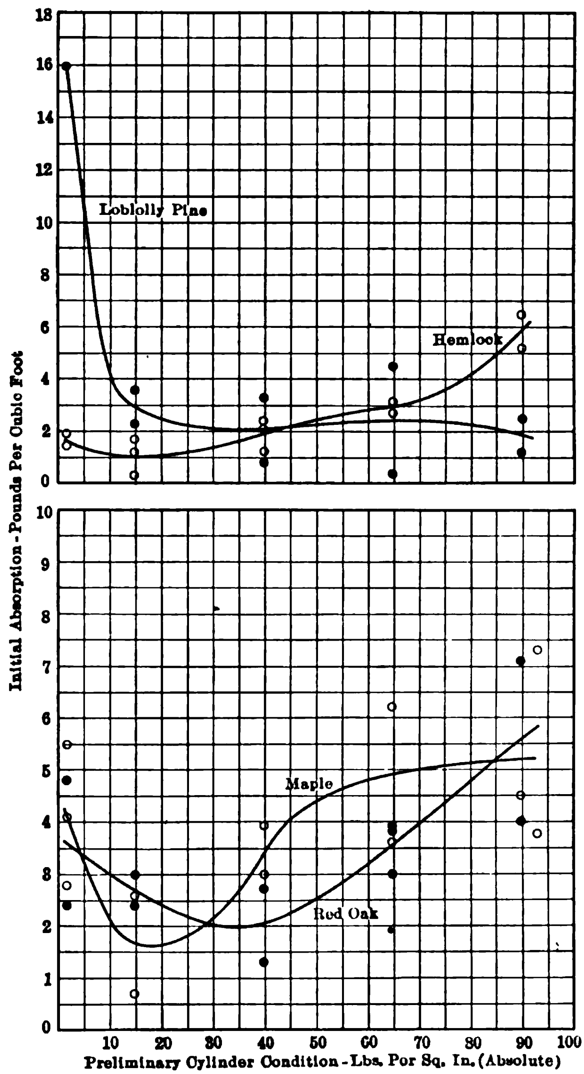


FIG. 16.—Showing the effect of air in ties upon the "Initial Absorption" of creosote.

a long time to escape—several days in some cases—and that this causes either a large drip or volatilization of preservative or both.

The effect of a preliminary air pressure is, then, to:

1. Increase the amount of preservative absorbed during the filling of the

cylinder over what is absorbed when only atmospheric pressure is used (Fig. 16).

2. Increase the length of time pressure must be held on the preservative in order to obtain the desired absorption. This is but slight, however, in woods like red oak but considerable in resistant woods like hemlock (Fig. 12).

3. Increase the amount of preservative which rebounds or "kickback" from the wood on release of pressure (Fig. 12).

4. Increase the amount of drip (Figs. 12, 13).

5. Leave a minimum amount of preservative in the wood (Fig. 14).

A "final air pressure" is seldom used. It was originally advocated to force the preservative deeper into the wood and thus produce an "empty-cell" effect. While it tends to do this to a slight extent, nevertheless it exerts a more pronounced action in removing some of the preservative. This is probably due to the fact that when pressure is released the air escapes from the wood and carries some of the preservative with it.

**The Effect of Pressure on the Preservative.**—In applying pressure to a preservative in a treating cylinder three factors are of importance: The intensity of the pressure, the duration of the pressure, and the rate at which the pressure is applied.

In general, the higher the pressure the greater and more rapid the penetration. On porous woods, high pressures are not necessary and, in fact, often objectionable because they force the preservative too rapidly into the wood and cause irregular penetrations. With resistant woods, high pressures (175 pounds per square inch or over) are also of little value because the resistance of the wood is often so great that the application of excessive pressure—even 500 pounds per square inch or more—is not sufficient to overcome this resistance. Working pressures of from 100 to 150 pounds per square inch give most general satisfaction.

As the wood cells are minute and the channels through which the large portion of the preservative passes are frequently microscopic in size, it is necessary to allow sufficient time for the preservative to diffuse through them. If the desired absorption of preservative is secured in a short period, the penetration is apt to be very irregular, whereas if the same absorption is obtained in a longer period a more uniform distribution is generally secured. The ideal result is to have the preservative diffused through the wood uniformly and deeply. The application of a lower pressure held for a longer time approaches this result better than a high pressure held for a short time. Its chief disadvantage

is a decrease in the capacity of the plant. The rate at which the pressure is applied to the preservative is also important. If it is applied rapidly up to the maximum, and the maximum is high, the desired absorption will be obtained in the shortest time but at the expense of greatest diffusion. A rapid application of pressure with a comparatively low maximum is better practice. If, however, the operator wants capacity, and a large rebound or "kickback" of preservative after the pressure is released, a rapid application of high pressure is the thing to use. The erratic penetration due to a quick absorption may be compensated for, in part at least, if the operator forces into the wood more preservative than he intends to leave in it, and counts upon the "kickback" to remove the surplus preservative. As has been shown above, the condition of the air in the timber also produces a marked effect upon the amount of preservative which rebounds out of the wood when pressure is released.

**Some Common Errors and Difficulties in Operating Pressure Plants.**—Even in the best equipped and managed plants, mechanical errors and difficulties in operation are almost daily encountered. Without going into the details characteristic of each process, the following general notes may be found of service, particularly to operators and inspectors.

**Difficulty of Measuring Volume of Charge.**—The volume of the timber in the treating cylinder could easily be determined, irrespective of its form, by subtracting the quantity of preservative it takes to fill the cylinder when charged from that necessary to fill it when empty, and deducting the volume of the cars, were it not for the fact that the wood will absorb the preservative while the cylinder is being filled. The amount absorbed varies with the kind and condition of the wood, being greatest in the case of porous woods air-dry and least for resistant woods when green, but generally ranges from about 5 to 20 percent. Some treating plants allow for this "initial absorption," and deduct 10 percent from the total amount of preservative to be forced into the wood after pressure is applied.[1] There is no satisfactory way of determining just what this initial absorption will be, and it must be worked out through experience at each plant. The

[1] Some treating engineers claim that blowing the preservative out of the treating cylinder into the measuring tank also blows some of the preservative out of the wood, especially if it is porous. As shown above (see "final air pressure"), this is quite likely to occur.

volume of sawed timbers can usually be determined with sufficient accuracy by direct calculation.

**Expansion of Creosote.**—Creosote expands considerably when heated, averaging about 1 percent for every 22 1/2° F. rise in temperature. It is frequently run into the treating cylinder at about 200° F. and its temperature invariably falls from 10° to 60° when it strikes the timber. Unless brought back to its temperature at entrance this contraction may be charged against absorption. Similar errors will be introduced in taking the final reading of absorption when the height of the oil in the measuring tank after the treatment has been completed is subtracted from the height before treatment, unless the temperature at both times is the same. It is important, therefore, to keep the temperature of the oil as nearly constant as possible (with no greater variation than 20° F.); or, if this cannot be done, to correct for temperature errors by using the proper coefficients of expansion. For zinc treatments and others of a similar nature such corrections need not be made.

**Expansion of the Cylinder.**—When hot creosote enters the comparatively cool treating cylinder it produces an expansion of the metal, which is further augmented by an internal pressure often as high as 175 pounds per square inch. For ac ylinder made of 3/4-inch boiler steel, 7 feet in diameter and 132 feet in length, this increase in volume may amount to about 18 cubic feet, equivalent to an absorption of about 1187 pounds of preservative.

**Compression of the Oil and Wood.**—When pressure is applied to creosote the oil is compressed. At most, however, this can produce only an insignificant error, since creosote under ordinary operative conditions compresses less than one-tenth of 1 percent. The error due to the compressibility of the wood is also insignificant. Some tests were made at the U. S. Forest Products Laboratory in which 20 pieces of green red oak and black oak, 2 by 2 inches in cross section, were tested in a 100,000-pound machine, the load being applied radially and tangentially. The average modulus of elasticity was 50,375 pounds per square inch. Disregarding the longitudinal dimension, the volumetric compression due to an exterior pressure of 200 pounds per square inch ranged from 0.51 to 1.30 percent, or an average of 0.80 percent. This compression is probably much in excess of that which takes place in practice, since when wood is submerged in a

preservative fluid the pressure is applied from all directions. Furthermore, at least a part of this pressure is transmitted to the interior. It would seem, therefore, that the decrease in the volume of wood undergoing treatment, due to the pressure exerted on it, can be entirely disregarded.

**"Kickback" of Preservative.**—When pressure is applied to a cylinder charge, the oil, wood, and air confined in the wood are under compression and the cylinder is under tension. If the pressure is released a certain amount of the preservative will be forced out of the cylinder, although it remains constantly full. The amount of preservative thus forced out will be called the "kickback." It varies with many conditions, and unless provided for may result in errors of measurement for absorption of from 10 to 40 percent. In the treatment of air-seasoned red oak and maple ties at the U. S. Forest Products Laboratory by the full-cell process it was necessary, after the desired absorption had been reached, to allow from 20 to 30 percent for the oil which did not remain in the ties.

To secure data on the variability of the "kickback" a careful series of tests was run on 36 pieces of air-dry longleaf pine. These were cut 2 inches by 4 inches by 4 feet, matched, divided into three groups of 12 each, and treated in three different runs in a cylinder approximately 18 inches in diameter and 4 feet long. In all cases the drip was stopped when it amounted to less than 1/2 pound of creosote in a half-hour period. The runs were made as follows:

**Run 1.**—No preliminary or final vacuum was used. The cylinder was filled with creosote in 6 minutes and the oil raised to a temperature of 180° F. A pressure of 120 pounds per square inch was immediately applied and held for 7 minutes. The pressure was then released through the top of the cylinder for 15 minutes, after which the cylinder was drained and the wood permitted to drip for 121 minutes, when it was removed and weighed.

**Run 2.**—After the wood was placed in the cylinder a preliminary vacuum of 25 1/2 inches was held for 15 minutes, the total vacuum period amounting to 22 minutes. Without breaking the vacuum the creosote was then drawn into the cylinder, the operation consuming 5 minutes. The temperature of the creosote on entering the cylinder dropped to 125° F. It was raised to 181° F. in 12 minutes, when a pressure of 120 pounds per

square inch was immediately applied and held for 3 minutes. The pressure was then released for 16 minutes through the top of the cylinder, after which the cylinder was drained and the wood permitted to drip for 73 minutes, when the charge was removed and weighed.

**Run 3.**—A preliminary air pressure of 50 pounds per square inch was immediately applied and held for 15 minutes, after which the oil was pumped into the cylinder against this pressure, the operation taking about 10 minutes. The temperature of the oil on entering the cylinder dropped to 156° F. It was then raised to 180° F., consuming 9 minutes. During the heating period the pressure in the cylinder varied between 55 and 70 pounds per square inch. As soon as the oil reached 180° F. a pressure of 120 pounds per square inch was applied and held for 78 minutes. The pressure was then released through the top of the cylinder for 14 minutes, after which the cylinder was drained and the wood permitted to drip for 128 minutes, when the charge was removed and weighed.

The results of these runs are given in Table 7. It will be seen that the "kickback" was least when a preliminary vacuum was drawn, and greatest when the cylinder was first filled with compressed air.[1] Similar results were secured on full-sized ties, as is shown in Figs. 12 and 13.

To illustrate the possible source of error through this "kickback" on the release of pressure, suppose, for example, it amounts to 20 percent, and the specifications call for a 10-pound per cubic foot injection in cross-ties of 3.5 cubic feet each. If the "kickback" is disregarded and the pumps kept running until the gauges show an injection of 10 pounds per cubic foot and the pressure is then released, only 8 pounds per cubic foot will be left in the ties. If, on the other hand, the "kickback" is considered, then the pumps will be kept running until the gauges indicate an absorp-

[1] When the preliminary vacuum was drawn, only 3 minutes of oil pressure were required to force 12.3 pounds of oil per cubic foot into the wood, but when the cylinder and wood were first filled with compressed air it took 78 minutes to force 12 pounds of oil per cubic foot into the wood. That the preliminary vacuum rendered it easier to force the preservative into the wood is therefore apparent. After the run the sticks were split and the penetration in run 3 was found to be slightly greater than in runs 1 and 2. Furthermore, the sticks in run 3 were treated more uniformly than in the other runs, especially run 2, in which the penetration and absorption were very irregular.

TABLE 7.—"KICKBACK" OF CREOSOTE ON THE RELEASE OF PRESSURE IN A TREATING CYLINDER

| Run no. | Pressure period | | Temperature of preservative in treating cylinder | Maximum amount of preservative forced into wood at end of pressure period per cubic foot | "Kickback" or amount of preservative forced out of cylinder on release of pressure | | | Oil recovered by drip | | Final absorption (oil remaining in wood after "kick-back" and drip) per cubic foot |
|---|---|---|---|---|---|---|---|---|---|---|
| | Time | Pressure per square inch | | | Amount per cubic foot | Time | Maximum absorption | Amount per cubic foot | Time | |
| | Min. | Pounds | °F | Pounds | Pounds | Min. | Percent | Pounds | Min. | Pounds |
| 1 | 7 | 120 | 180–185 | 12.9 | 4.80 | 15 | 37.0 | 0.9 | 121 | 7.2 |
| 2 | 3 | 120 | 180–181 | 12.3 | 2.40 | 16 | 20.0 | 0.5 | 73 | 9.4 |
| 3 | 78 | 120–130 | 180–181 | 12.0 | 4.50 | 14 | 37.5 | 1.0 | 128 | 6.5 |

tion of 12.5 pounds per cubic foot, which on the release of pressure will leave 10 pounds per cubic foot in the ties. If this "kick-back" is released through an underground tank or some measuring tank other than the one used during treatment (and this is a common practice), the chances for error in measuring the absorption are increased.

**Expansion of Wood.**—Another possible source of error in measuring absorption is the expansion of the wood due to raising its temperature. Assuming the thermal coefficient of linear expansion of wood, 0.00001 per degree Centigrade parallel to the fiber and 0.00006 across the fiber[1] and that the wood is raised in temperature 60° C. (140° F.) during treatment, then the increase of volume in a charge of say 800 ties will be about 22 cubic feet, equivalent to about 1,386 pound of creosote, or 1.7 pounds per tie. If the wood is raised more than 60° C. in temperature, the volume increase will, of course, be greater.

**Extent of Possible Errors.**—The extent of the various errors possible in measuring absorption may be illustrated by the following example: Assume the treating cylinder to be 7 feet in diameter, 132 feet long, and to hold a charge of 800 7-inch by 9-inch by 8-ft. ties; assume also that 10 pounds of creosote per cubic foot are to be injected into and left in the ties; that a pressure of 175 lb. per square inch is used during the treatment; that the oil in the measuring tank is maintained at 200° F. and is in-

[1] Experiments of Glatzel and Villari: Smithsonian physical tables, 5th rev. ed., p. 223.

jected into the wood at 180° F.; and that the normal temperature of the cylinder and wood is 60° F. With all gauges working perfectly, no leaks of any kind occurring, all air out of the cylinder when the oil pump is started, and the volume of the ties accurately known, the following errors may take place:

| | Pounds per tie |
|---|---|
| 1. Chargeable to contraction in the volume of creosote.......... | 1.85 |
| 2. Chargeable to the expansion of the cylinder due to temperature | 1.35 |
| 3. Chargeable to the "kickback" (assumed to be 20 percent of the absorption) .......... | 7.00 |
| Total positive errors.......... | 10.20 |
| 4. Chargeable to the expansion of the wood .......... | 1.50 |
| Total in excess of apparent absorption .......... | 8.7 |

Thus, out of a total specified injection of 10 pounds per cubic foot, or 35 pounds per tie, 8.7 pounds per tie may be forced into the cylinder, but either will not go into or not remain in the ties, constituting a total error of about 25 percent. In plants operating with zinc chloride, item 1 may be eliminated and item 3 will be less than that given.

**Purity of the Preservative.**—The composition of the preservative is subject to change so that check analyses of it should be made from time to time to see that it meets specifications.

With creosote, the chief difficulty likely to occur is with the water content of the oil. Leaky steam coils, or snow or ice on the wood, or water in the wood are all liable to adulterate the oil with water. It is not necessary to remove all of the water but large amounts (over 5 percent) are objectionable and it is not good practice to allow for this by giving the timber a heavier injection. Proper procedure is to remove the water. This may be done in some cases by allowing the oil to stand for several days in a tank,[1] when the water may be drawn from the top of the oil, or by boiling off the water in tanks equipped with steam coils. In either case loss of some oil is almost sure to occur.

It sometimes happens that the carbon content of the creosote will increase as it is used over and over again, so that timber treated with "old" oil will look much blacker than timber treated with "fresh" oil. The author has known of inspectors refusing

[1] Some engineers alternately heat and cool the oil several times before drawing off the water.

to accept treated timber because it did not look "black." Free carbon will not penetrate wood, has no preservative value, and detracts from the quality of the oil. About the only practical way to guard against too large a percentage of free carbon is to be careful in the purchase of the oil.

It is also asserted, at times, that the composition of creosote changes because that portion of it which enters the wood and is then redrawn carries with it some of the soluble constituents in the wood. While there is a possibility of its doing this, careful tests have failed thus far to show any marked changes in the oil due to this cause.

Solutions of zinc chloride also need careful attention. Common practice is to place a hydrometer in the solution and if it shows correct gravity to assume the strength to be correct. This practice is subject to error because foreign substances such as other inorganic salts or materials dissolved from the wood may change the gravity. Some careful tests made at the U. S. Forest Products Laboratory have also shown that the strength of a zinc-chloride solution may be changed by successive treatments, the solution tending to weaken.

**Pollution of Streams.**—Complaint has been made against some treating plants because they polluted streams with waste oil. This comes largely from the cylinders and steam exhausts. Of course, no plant is going to deliberately waste preservative and it is believed that such complaints can be entirely avoided as they are indications of bad management. The use of a final vacuum in drying the timber, and attention to steam coils to see that they do not leak, will remedy much of the difficulty. All drains can be carried to a common settling tank, where by a system of overflow chambers arranged in the tank practically no oil will escape.

**Inspection of Treatments.**—Controversies between purchasers of treated timber and operators of treating plants over the inspection of treatments have been no more common than in other industries which are of comparatively new growth and where so many factors are involved, but much needless dispute has occurred because one party or the other has not been sufficiently trained to recognize legitimate demands. Attempts to cover up fraudulent work have, of course, been made and probably will be as long as the industry exists, but such cases are decidedly in the minority, for corrupt practice sooner or later becomes generally recognized and eventually kills itself.

Much of the trouble can be laid entirely on the purchaser, who frequently insists upon impractical specifications and unattainable results. It is the author's opinion that considerable freedom should be given the operator as regards the details of the treatment, and that only a few essential features need be required. We will attempt to give here only those which are more important and applicable to general conditions.

First, perhaps, comes the wood itself. It should be remembered that wood is a product grown under a wide variety of conditions and hence varies greatly in its structure. It is practically impossible to get two pieces which are alike, and therefore specifications for wood should not be too stringent. It is reasonable to expect, however, that *only sound wood* be furnished. In this connection, wood which is sap-stained should not be confused with wood which is decayed. In specifying rings per inch, knots, crooks, tapers, etc., care should be exercised so that the specifications *are reasonable* and do not require the rejection of large quantities of good material. As regards the kinds of wood, the specifications should recognize that the same kind may go under a variety of names; hence no chance for misunderstanding should be left.

The *composition of the preservative* to be used should be clearly stated and also its method of analysis, and the inspector should be granted permission to take samples for analysis as often and from whatever source he pleases. Requirements in this regard can be made fairly rigid.

The treating operator can also be held to have his plant in fit condition for accurate work, and if considered necessary the inspector can measure all essential pieces of apparatus in order to make sure the dimensions furnished are correct. Errors in operation already described should be recognized, so that they can be taken into account in making determinations of absorption. As for the treatment proper, the essentials to specify are the *maximum temperatures* to be used and the *absorption of preservative* required. This should be *final absorption*, or the amount of preservative actually in the wood at the time it is removed from the cylinder, free from drip. Because wood varies so, it should not be expected that *all pieces* are to have the *same absorption*. They may vary widely. In all cases, as deep and uniform a penetration as possible should be required, and the inspector should

know *what is possible before* he attempts to pass judgment on the results. A *complete penetration of all sapwood* should always be secured and the specifications should be so framed as to admit of this. Woods which vary widely in their resistance to injection should not be treated in the same charge; neither should the mixing of green and seasoned wood in the same run be allowed. In all cases the difference in the height of the preservative in the measuring tank *before and after* the treatment has been made should furnish the final basis for determining the absorption secured; or if seasoned wood is treated, the weights on the track scales should be used. Sources of error due to friction of gauges, differences in temperatures, etc., should be carefully considered in determining final absorption.

**The Cost of Pressure Plants.**—The cost of pressure plants is exceedingly variable even for plants of the same capacity. Any estimate, therefore, must be considered with a wide latitude. The variations in cost are due largely to the type of buildings, the number of processes practised, the yard layout, and local soil and surface conditions. The author knows, for example, of two plants with cylinders approximately 6 feet 2 inches in diameter by 132 feet in length, equipped to treat timber by the same methods, one of which cost $65,000 and the other $170,000 complete.

With these variations in mind, the following estimate of a 2-cylinder plant with cylinders 7 feet in diameter by 132 feet in length, equipped to treat by any standard process and of first class construction, is given:

| | |
|---|---|
| Track and grading | $35,000 |
| Retorts with all piping installed | 13,000 |
| Three 150 H.P. boilers complete | 4,000 |
| Sewers | 1,500 |
| Buildings | 30,000 |
| Pumps (compressor, vacuum, hydraulic, service) | 5,000 |
| Piping, valves, complete | 7,000 |
| Fire hydrants and equipment | 3,500 |
| Electric plant complete | 4,000 |
| Miscellaneous plant items | 4,000 |
| One 12-ton locomotive crane | 4,200 |
| One dummy engine | 3,000 |
| Cylinder cars (190) | 8,500 |
| Total | $122,700 |

TABLE 8.—APPROXIMATE COSTS OF COMPLETE TIMBER PRESERVING PLANTS

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of cylinders | | 1 | | 1 | | 1 | | 1 | | 2 | | 3 | | 4 | |
| Size of cylinder | | 74×42 | | 74×50 | | 74×108 | | 74×132 | | 74×132 | | 74×132 | | 74×132 | |
| Acres required for complete plant and yard. | | 7 | | 8 | | 10 | | 20 | | 39 | | 59 | | 78 | |
| Storage | Total ties | 170,000 | | 205,000 | | 260,000 | | 540,000 | | 1,080,000 | | 1,620,000 | | 2,160,000 | |
| | Equivalent in thousand board feet of lumber. | 7,040 | | 8,490 | | 10,770 | | 22,400 | | 45,000 | | 67,000 | | 90,000 | |
| Capacity | Creosote in gallons | 110,000 | | 133,000 | | 168,000 | | 350,000 | | 700,000 | | 1,000,000 | | 1,400,000 | |
| | Water in gallons | 7,200 | | 8,500 | | 11,000 | | 22,500 | | 45,000 | | 67,500 | | 90,000 | |
| Total miles of track in yard | | 1.00 | | 1.23 | | 1.23 | | 2.8 | | 5.6 | | 7.7 | | 9.8 | |
| Length of loading platform | | 126 ft. | | 150 ft. | | 325 ft. | | 400 ft. | | 400 ft. | | 530 ft. | | 660 ft. | |
| Particulars of Costs | | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ |
| Machinery | | 61.00 | 10,600 | 70.00 | 13,200 | 131.00 | 21,200 | 163.00 | 25,700 | 278.00 | 42,000 | 363.00 | 54,400 | 458.00 | 66,900 |
| Creosote Tanks | | 24.30 | 1,900 | 29.00 | 2,260 | 36.50 | 2,850 | 45.00 | 3,900 | 90.00 | 6,950 | 123.00 | 9,500 | 205.00 | 16,000 |
| Water tanks | | 3.00 | 360 | 3.70 | 440 | 4.80 | 570 | 9.70 | 1,160 | 17.50 | 2,100 | 27.00 | 3,200 | 35.00 | 4,200 |
| Tram cars | | 25.00 | 1,980 | 28.30 | 2,340 | 61.00 | 4,860 | 75.00 | 6,000 | 148.00 | 11,820 | 220.00 | 17,580 | 293.00 | 23,400 |
| Fire service | | 11.50 | 800 | 13.60 | 950 | 17.20 | 1,200 | 35.80 | 2,500 | 71.60 | 5,000 | 105.00 | 7,300 | 140.00 | 9,800 |
| Yard hoists | | 3.60 | 600 | 4.00 | 700 | 7.50 | 1,200 | 9.00 | 1,500 | 18.00 | 3,000 | 20.00 | 3,200 | 22.00 | 3,400 |
| Steel Buildings | | 15.00 | 1,600 | 17.80 | 1,900 | 27.20 | 2,900 | 30.00 | 3,200 | 37.40 | 4,000 | 67.50 | 7,200 | 84.00 | 9,000 |
| Excavating and foundations | | ...... | 1,150 | ...... | 1,350 | ...... | 2,000 | ...... | 2,250 | ........ | 2,800 | ........ | 5,000 | ........ | 6,300 |
| Loading platform | | ...... | 630 | ...... | 750 | ...... | 1,625 | ...... | 2,000 | ........ | 2,750 | ........ | 3,640 | ........ | 4,500 |
| Tracks | | 105.00 | 5,400 | 130.00 | 6,600 | 130.00 | 6,600 | 294.00 | 14,900 | 590.00 | 29,800 | 810.00 | 41,000 | 1,040.00 | 52,600 |
| Land | | ...... | 700 | ...... | 800 | ...... | 1,000 | ...... | 2,000 | ........ | 3,900 | ........ | 5,900 | ........ | 7,800 |
| Total | | 248.40 | 25,720 | 296.40 | 31,290 | 415.20 | 46,005 | 661.50 | 65,110 | 1,250.50 | 114,120 | 1,735.70 | 157,980 | 2,277.00 | 203,900 |

Tie storage is based on 75 percent of the yearly capacity of plant, or 9 months seasoning.
Creosote oil storage is equal to 60 days supply when running.
Track is based on 60 pounds per yard rail. Steel at $30.00 per ton, ties at 50c. each and laying tract at 10c. per foot.
Retorts are designed for working pressure of 250 pounds per square inch.
Plants are arranged for either Burnettizing, Wellhouse, Full Cell, Rueping, Lowry or Card process.
Hoists are for transferring tram. If electrical locomotives are to be used, add or deduct in accordance.
Where plants are treating piling and timber it is necessary to have a traveling yard crane, which will cost about five to seven thousand dollars, depending on capacity.

TABLE 8.—APPROXIMATE COSTS OF COMPLETE TIMBER PRESERVING PLANTS.—*Continued*

| Number of cylinders | 5 | | 6 | | 1 | | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Size of cylinders | 74 × 132 | | 74 × 132 | | 84 × 108 | | 84 × 132 | | 84 × 132 | | 84 × 132 | | 84 × 132 | |
| Acres required for complete plant and yard. | 98 | | 117 | | 21 | | 26 | | 47 | | 78 | | 104 | |
| Storage: Total ties | 2,700,000 | | 3,240,000 | | 585,000 | | 720,000 | | 1,290,000 | | 2,160,000 | | 2,880,000 | |
| Storage: Equivalent in thousand board feet of lumber. | 112,000 | | 134,000 | | 24,200 | | 30,000 | | 53,500 | | 90,000 | | 118,000 | |
| Capacity: Creosote in gallons | 1,700,000 | | 2,000,000 | | 380,000 | | 500,000 | | 1,000,000 | | 1,500,000 | | 2,000,000 | |
| Capacity: Water in gallons | 110,000 | | 135,000 | | 25,000 | | 30,000 | | 60,000 | | 90,000 | | 120,000 | |
| Total miles of track in yard | 12.5 | | 14.2 | | 2.84 | | 3.5 | | 6.1 | | 10.00 | | 12.8 | |
| Length of loading platform | 660 ft. | | 800 ft. | | 325 ft. | | 400 ft. | | 400 ft. | | 530 ft. | | 700 ft. | |
| Particulars of costs | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ | Wgt. in tons | Cost $ |
| Machinery | 544.00 | 79,400 | 634.00 | 85,900 | 185.00 | 28,900 | 225.00 | 34,700 | 384.00 | 57,800 | 507.00 | 89,200 | 656.00 | 109,800 |
| Creosote tanks | 225.00 | 17,600 | 243.00 | 19,000 | 52.50 | 4,100 | 61.50 | 4,750 | 123.00 | 9,500 | 184.50 | 14,250 | 246.00 | 19,000 |
| Water tanks | 44.00 | 5,230 | 53.00 | 6,300 | 10.80 | 1,290 | 13.00 | 1,550 | 24.00 | 2,870 | 35.00 | 4,200 | 48.00 | 5,740 |
| Tram cars | 365.00 | 29,160 | 440.00 | 35,040 | 66.00 | 4,290 | 82.00 | 6,500 | 160.00 | 12,805 | 240.00 | 19,045 | 319.00 | 25,350 |
| Fire service | 177.00 | 12,400 | 208.00 | 14,500 | 37.00 | 2,600 | 47.00 | 3,250 | 83.00 | 5,800 | 1,400.00 | 9,750 | 1,860.00 | 13,000 |
| Yard hoists | 24.00 | 3,600 | 26.00 | 3,800 | 10.00 | 1,600 | 12.00 | 2,000 | 24.00 | 4,000 | 25.00 | 4,200 | 26.00 | 4,400 |
| Steel Buildings | 101.00 | 10,800 | 114.00 | 12,000 | 32.70 | 3,500 | 41.00 | 4,400 | 59.00 | 6,300 | 801.00 | 8,600 | 1,000.00 | 10,700 |
| Excavating and foundations | ........ | 7,600 | ........ | 8,400 | ...... | 2,450 | ...... | 3,100 | ........ | 4,400 | ........ | 6,000 | ........ | 7,500 |
| Loading platform | ........ | 4,950 | ........ | 6,000 | ...... | 1,625 | ...... | 2,000 | ........ | 3,000 | ........ | 4,500 | ........ | 5,600 |
| Tracks | 1,310.00 | 63,000 | 1,500.00 | 74,500 | 300.00 | 15,200 | 370.00 | 18,700 | 640.00 | 32,200 | 1,070.00 | 53,600 | 1,500.00 | 73,800 |
| Land | ........ | 9,800 | ........ | 11,700 | ...... | 2,100 | ...... | 2,600 | ........ | 4,700 | ........ | 7,800 | ........ | 10,400 |
| Total | 2,790.00 | 243,540 | 3,218.00 | 277,140 | 694.00 | 67,655 | 851.50 | 83,550 | 1,497.00 | 143,375 | 4,252.50 | 221,145 | 5,655.00 | 285,290 |

**Tie storage is based on 75 percent of the yearly capacity of plant, or 9 months seasoning.**
Creosote oil storage is equal to 60 days supply when running.
Track is based on 60 pounds per yard rail. Steel at $30.00 per ton, ties at 50c. each and laying track at 10c. per foot.
Retorts are designed for working pressure of 250 pounds per square inch.
Plants are arranged for either Burnettizing, Wellhouse, Full Cell, Rueping, Lowry or Card process.
Hoists are for transferring tram. If electrical locomotives are to be used, add or deduct in accordance.
Where plants are treating piling and timber it is necessary to have a traveling yard crane, which will cost about five to seven thousand dollars, depending on capacity.

Through the courtesy of the Allis-Chalmers Company, the author is able to give Table 8, which contains estimates of the cost of wood preserving plants of various capacities. The plants given in the table are arranged for either the Burnett, Wellhouse, Bethel, Rueping, Lowry, or Card process. In using this table, variations of at least 20 percent either way can be expected.

# CHAPTER VIII

## PROLONGING THE LIFE OF CROSS-TIES FROM DECAY AND ABRASION

**Selection of Species.**—At the present time, practically any kind of tree which is large enough to make a cross-tie is used for this purpose. The result is a great variety of ties differing widely in their properties. It stands to reason, therefore, that the service obtained from ties must be very erratic. The difficulty now generally experienced by many American railroads to secure adequate supplies of good ties makes it impossible to be too stringent in specifying the kinds of wood which will be used. If planting trees for ties becomes general, the question of proper selection of species will be a very important one, but at the present time this feature is recognized only in the price paid for ties and no special selection is made.

Common practice now consists in dividing the various kinds of ties into two groups, viz., ties to be used without preservative treatment and ties to be treated. The former group includes those woods which are naturally durable, the latter those which if placed in a track untreated would decay in a few years.

The ideal tie for use without treatment is one which is not only very resistant to decay but which is hard and will hold spikes and resist rail cutting without serious splitting or checking. Of our more common American woods, black locust and white oak best meet these requirements. Redwood, cedar, and cypress are very durable but are inferior to black locust and white oak as regards strength.

If the tie is to be treated, the prime qualities are strength, hardness, and permeability. Red oak, maple, birch, beech, and elm best fulfill these conditions. A large variety of other woods are, of course, also used, chief among which are the pines, firs, spruces, gums, hemlocks, chestnut, and tamarack. Irrespective of marketing conditions, the value of these woods for tie purposes depends directly upon their ability to meet the requirements just mentioned. In other words, a wood which is hard and por-

ous is more valuable for a "treatment tie" than a wood which is soft and resistant to impregnation, and should therefore command a higher price. Maple, for example, is worth more *for a cross-tie* than white pine or spruce beeause, when treated, it will give better service.

Unfortunately, conditions are still such in our country that many trees are cut for ties which ought to be cut for more valuable products such as veneer or lumber. Black walnut, cherry, and hickory are conspicuous examples. Where these trees occur scattered in forests or woodlots, it is often easiest to market them in the form of ties, but whenever possible, they should not be used for this purpose, as it results in a distinct economic loss of valuable material.

**Hewed Versus Sawed Ties.**—Approximately 75 percent of all ties purchased are hewed. In the tie industry as a whole the methods of manufacture are undergoing no general or permanent changes. The probable reasons are that the railroads obtain, either directly or indirectly through tie companies, a large proportion of their ties from farmers and small holders of timber who cannot afford to saw them, and also because the importance of utilizing timber to the best advantage has not yet been keenly felt. Under certain conditions the sawing of ties may be impracticable, as when, for example, only a few trees suitable for cross-ties are available, or when ties are cut from tops of felled trees. In such cases it is much better to utilize the wood by hewing it into ties than to leave it in the forest. The claim is often made that hewed ties are more durable than sawed ties because they shed water better. Nothing is known by the U. S. Forest Service to substantiate this impression. Even if untreated hewed ties should be more durable than sawed ones, this advantage disappears when the ties are treated. On the other hand there are many serious objections to the use of hewed ties, and these will increase in importance in direct proportion to the number of ties treated with preservative. Chief among these objections are (1) unequal bearing afforded tie plates and rails, (2), lack of uniform volume, and (3) unnecessary waste of valuable material.

**Bearing Afforded Tie Plates and Rails.**—The heavy tonnage on American railroads necessitates the use of some form of tie plate on practically all first-class construction. Hewed ties seldom offer a uniform bearing surface to the plate or rail, and

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unless specially adzed before placement soon wear unevenly and must be removed. An inspection of test ties on the Chicago & Northwestern track showed in many cases that one edge of the plate had cut into the tie to a depth of over 1/2 inch, while the other edge was not even flush with the surface. With sawed ties the bearing over the surface is more uniform and rail cutting is considerably reduced. The introduction of tie-boring and adzing machines is doing much to improve the bearing of plates on the ties and should cut down mechanical wear appreciably.

**Uniformity in Volume.**—Since tie inspectors offer no objection to, but rather favor, ties of greater dimensions than those specified, the tie manufacturer rarely hews a large log to the standard size. Thus the cubic content of hewed ties may vary from that of the uniform dimensions allowed to about twice the size specified. Practically all contracts for treating ties state that so much preservative shall be injected per cubic foot of wood. With hewed ties no treating plant knows accurately what this volume is until after the ties have been treated. To obtain the total quantity of preservative to be used, it is customary to figure that a tie will contain a certain amount of wood, and to multiply this figure by the number of ties and the amount of preservative to be injected per cubic foot. For example, to figure the amount of creosote needed to treat 1000 cross-ties 6 inches by 8 inches by 8 feet with 10 pounds of oil per cubic foot, the calculation would be $1000 \times 2.67 \times 10 = 26{,}700$ pounds. If the hewed ties average 3.2 cubic feet, though figured as of standard size, the total amount of preservative would be the same, viz., 26,700 pounds, but the amount per cubic foot would be only 8.3 pounds instead of 10, as specified. Sawed ties are cut to more exact dimensions, and errors of this kind are improbable.

**Waste of Material.**—To hew a tie necessarily entails an enormous waste of material. Based on actual field data the waste by hewing varies from 25 to 75 percent[1] (Fig. 17). Logs 15 inches in diameter furnish, as a rule, only one hewed tie, but if sawed they furnish two. Whenever possible the tie hewer selects trees of about 12 or 14 inches in diameter. The waste of wood each year in the United States from hewing ties amounts to about 285,000,000 cubic feet, a quantity equivalent to about 80 percent of the total amount of pulpwood used in the United States in

[1] U. S. Forest Service Bulletin 64, "Loblolly Pine in Eastern Texas, with Special Reference to the Production of Cross-ties," by Raphael Zon.

1909. This is an absolute waste, as it is not even used for fuel. (See Plate XIII, Fig. A.)

**Form of Cross-ties.**—Practically all of the wooden cross-ties now used on steam railroads in the United States are rectangular in cross section. Their size is by no means uniform, varying in width from 6 to 10 inches, in depth from 6 to 7 inches, and in length from 8 to 9 feet. These ties are sometimes cut either with a saw or axe on all four sides (see Plate XIII, Fig. B), in which case they are said to be "squared." In many cases only the top and bottom are cut, leaving the sides the natural shape of the tree. When thus made from small trees the ties are called "pole ties." In Europe a large number of ties are cut larger on the base than on the top and are commonly referred to as "half-round ties."

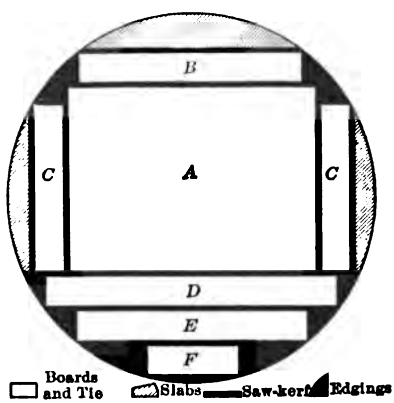


FIG. 17.—Ideal economy in manufacturing a cross tie. $A$ = tie 6 × 8 inches; $B$ = board 7 inches wide; $C. C.$ = boards 5 1/2 inches wide; $D$ = board 9 1/2 inches wide; E = board 7 1/2 inches wide; $F$ = board 3 inches wide. (Diagram courtesy of the Forest Service.)

Such ties are also used to a limited extent in our country. (See Plate XIII, Fig. C.) One railroad uses a form of tie which will economize in timber by cutting them triangular. (See Plate XIII, Fig. D.) It is believed that the form of cross-ties, especially as regards the distribution of the sapwood on them, is very important and an item too frequently overlooked in track construction. It is just as logical to specify how ties to be treated shall be sawed or hewed as regards their sapwood content and its distribution, as it is to specify a difference in price due to a difference in the kind of wood. Exceptions of course occur, as, for example, in those ties whose heartwood treats as easily

as the sapwood. Sapwood is easy to impregnate with preservatives, while the heartwood is generally very resistant. This difference in the resistance to treatment between the sap and heartwood of the same tie is often very much greater than the difference in treatment between two ties of widely different varieties of wood. In certain species like the red oak, hemlock, and the ash, this condition is not true, but in the majority of cases it is. With most ties composed of part heart and part sapwood, when placed in a cylinder and injected with a preservative, most, if not practically all of the preservative will go into the sapwood.

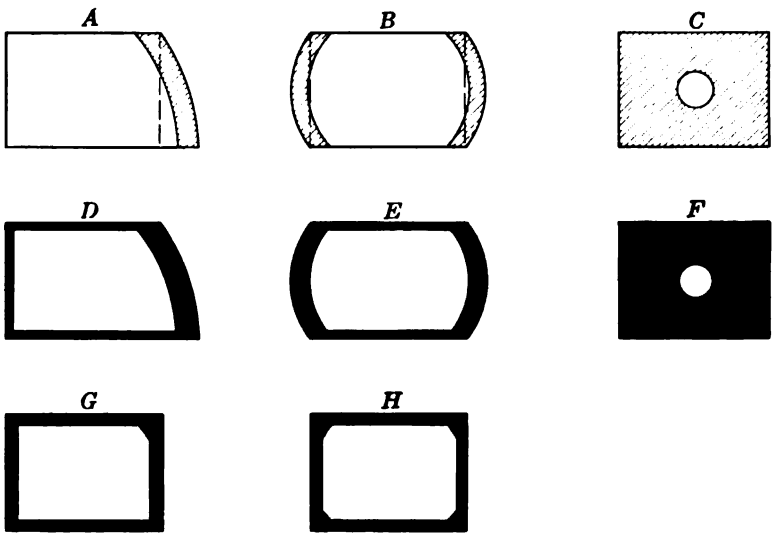


FIG. 18.—Showing the character of the preservative treatment in ties properly and improperly manufactured.

To secure best results it is of considerable importance, therefore, to specify how this sapwood should be distributed. The best kind of cross-tie intended for treatment is one which has a uniform distribution of sapwood on all surfaces (Fig. 18 C). A tie of this kind can be very efficiently protected against decay. Unfortunately, only a comparatively small number of ties are of this kind, and even those that are, are usually of low crushing strength. By far the largest percentage of ties now used are composed mostly of heartwood or needless sapwood, as shown in Fig. 18 A and Fig. 18 B. When ties of this kind are treated according to the ordinary run of specifications, practically all of the

FIG. A.—Method of hewing oak ties in Tennessee. Note waste. (Forest Service photo.)

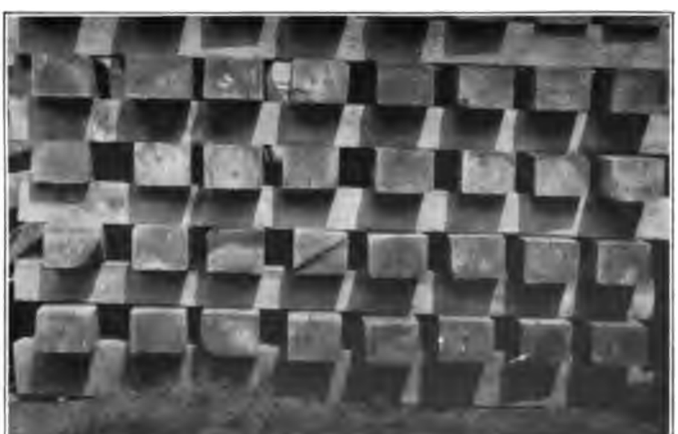

FIG. B.—Rectangular cross-ties—standard form in the United States.

(*Facing page* 132.)

FIG. C.—Standard Prussian ties of Baltic pine. (Forest Service photo.)

FIG. D.—Triangular cross-ties—Great Northern Ry. (Forest Service photo.)

preservative will go into the sapwood, leaving the heart faces with only a superficial penetration. The greatest wear on a tie comes on its face immediately under the rail or plate. This is the portion which should have the greatest and not the least protection against decay, as now generally occurs due to the present methods of manufacture. If ties of the type shown in Fig. 18 A and Fig. 18 B are treated, they can unquestionably be made to absorb the amount of preservative specified—say 10 pounds per cubic foot—but most of the preservative will be in those portions of the tie where it will do the least good. If, now, these ties were sawed as indicated by the dotted lines in the sketch, it would be possible to secure just as long a life from them with a much less consumption of preservative.

For example, consider a modern treating plant having an output of approximately 800,000 ties per year: If the ties are impregnated with 10 pounds of creosote per cubic foot, the oil costing 6 cents per gallon and the ties containing approximately 3 cubic feet, the total amount of the oil used would be approximately 24,000,000 pounds. If, now, the ties had been cut as indicated in the sketch, it would be possible with a consumption of about 6 pounds of creosote per cubic foot to protect them as effectively as with 10 pounds in the former case. This would result in a net saving of approximately 4 pounds per cubic foot or 12 pounds per tie, equivalent to about 9 cents per tie for cost of preservative, or $72,000 in one year's operation.

There are other ways in which this point could be argued. For example, if this unnecessary sapwood were removed, could not the life of the tie be increased over what it would have been, provided the quantity of oil injected in both cases remained the same? A company would be justified in paying more for properly sawed ties intended for treatment than for ties which are improperly sawed or hewed, especially when the treatment is one using straight coal-tar creosote. It is the author's opinion that roads using this method of treatment could very well afford to insert another clause in their specifications for cross-ties, concerning the amount and distribution of sapwood, and even go to the extent of paying a higher price for ties in which the sapwood was properly distributed. They would thereby save an appreciable item in the cost of treatment. The roads which do not use treated ties or which adhere to a zinc treatment would not be benefited to the same degree by a requirement of this kind.

Such procedure would simply be a step in advancing the increased efficiency with which cross-ties can be utilized, with a view to decreased cost in track maintenance and operation. The difficulties in putting it into practical use would, in some cases, be unsurmountable, but where conditions of production are such that a requirement of this kind could be employed, it is believed its adoption would unquestionably result in decided profit.

In Fig. 18, A, B, and C. represent the cross sections of three ties, the shaded portion being sapwood and the white, heart-

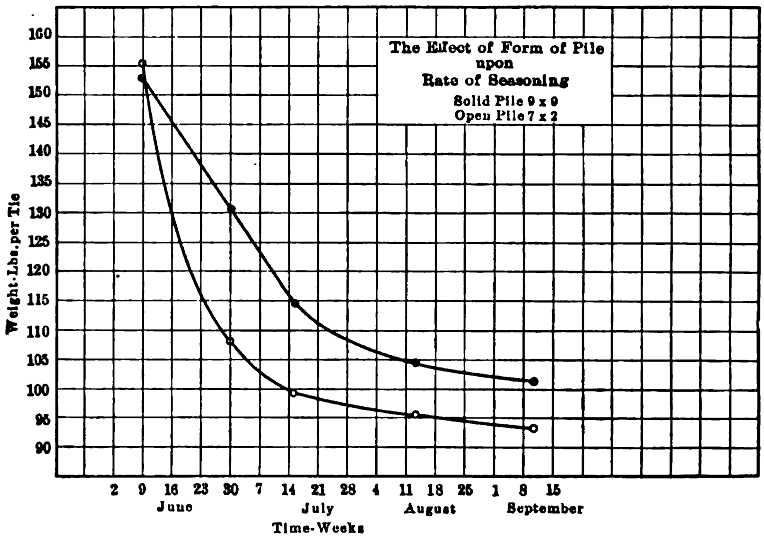


FIG. 19.—Effect of the form of piling upon the rate of seasoning of lodgepole-pine ties.

wood. The dotted lines show how these ties could be improved by slabbing the sides.

If impregnated with creosote, the ties would appear as in Figs. 18 D, E, and F. Note the heavy impregnation on the sides and the very slight impregnation on the faces in Figs. 18 D and E. Figs. 18 G and H show ties *A* and *B* slabbed on the sides and then impregnated with creosote. Note the even distribution of the preservative and the heavier injection on the faces than in D and E, thereby giving greater protection to the tie where it is most needed and at the same time consuming less of the preservative.

**Stacking Ties for Seasoning.**—Different kinds of wood and climate require different methods of piling. The closer the ties

are piled the slower will be their loss in weight. In no case should more than two ties in a pile come in contact with the ground. The most open form is the triangular one, which can be rapidly made and is well adapted for use along the right of way. It should not, however, be used for many hardwoods cut in summer, since these will check badly. Good forms of piles are the 7 by 2, 7 by 1, and 8 by 1. (See Plate XIV, Fig. A.) These are well adapted for softwoods and for most hardwoods cut in summer. They are easy to build and permit of free circulation of air. When it is desired somewhat to retard the rate of drying, the 8 by 2 or the 10 by 1 form should be used, or if these are still too open, the 7 by 7 form. An advantage of the 7 by 1, 8 by 1, 10 by 1, and similar forms is that no tie lies flat on another, thus giving an easy run-off for rain water and a free circulation of air. In practically no case should untreated ties be piled solidly 9 by 9, since such forms are exceedingly inefficient in regard to seasoning and invite decay. The effect of the form of piling upon the rate of seasoning is shown in Fig. 19.

Though the U. S. Forest Service has made many tests to determine the effect of different forms of roofs on the seasoning of ties, the data secured are not conclusive. However, a slanting roof of ties is fairly efficient in shedding water, and when not requiring too much additional labor can be employed advantageously.

Ties cut from conifers are less likely to check during seasoning than ties cut from broadleaf trees, and in consequence can be piled more openly.

If ties are seasoning too fast they should be piled closer together (see Plate XIV, Fig. B); if seasoning too slowly they should be piled more openly. Ties cut in winter can be piled more openly without danger of checking than ties cut in summer.

The length of time ties should season before treatment will vary primarily with the species of wood, form of pile, and period of the year. In general, ties cut in spring and summer will be seasoned sufficiently for treatment by the end of the following autumn; ties cut in early spring will be seasoned sufficiently by the following early autumn; the seasoning period varying from about 2 to 4 months. Ties cut in autumn and winter will be sufficiently seasoned by the end of the following spring, the period varying from about 5 to 8 months. The periods necessary

to season dense ties like the oaks will generally be from 2 to 3 months longer than those just given.

Figs. 20 and 21 illustrate these conditions; Fig. 20 representing red gum ties which season very rapidly and Fig. 21 red oak ties

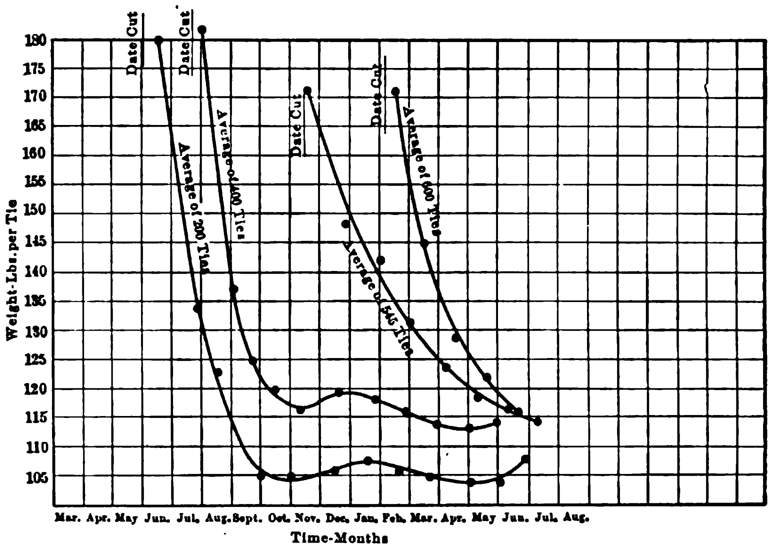


FIG. 20.—Rate of seasoning of red gum ties.

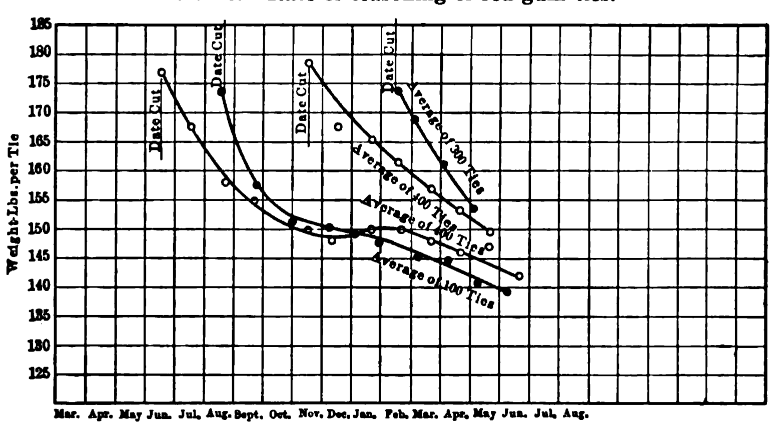


FIG. 21.—Rate of seasoning of red oak ties.

which season slowly. Both figures show the accelerated drying in the warmer months and the retarding action of winter.

**Grouping Ties to Secure Uniform Treatment.**—The importance of properly grouping ties before placing them in the treating

cylinder cannot be overemphasized. If ties offering unequal resistance to penetration are treated at the same time, those offering the greatest resistance will take practically no preservative, while the others will get it all. Consequently, if ties so treated are placed in a roadbed, the ones heavily injected will outlast the others and the wear on the track will not be uniform. Furthermore, when the ties inadequately treated decay, the load which should be borne by them will be transferred to the sound ones, hastening their mechanical destruction. Thus much of the preservative will be wasted, since there is no economy in preserving ties from decay after they have been worn out. The aim, therefore, should be to have the ties depreciate uniformly, and this can largely be brought about by grouping them in such a manner that they will receive equal amounts of the preservative uniformly diffused. Many tie plants already realize the importance of grouping, and consider the added expense more than justified by the results secured.

The chief factors which determine the ease with which ties may be impregnated are (1) the species of wood, (2) percent of sap and heartwood, (3) moisture content. The less important are conditions under which seasoned, time of cutting, and conditions of growth.

**Species of Wood.**—It has been explained in Chapter III that the species of wood differ greatly in their physical properties and that this difference accounts in a large measure for the variable results secured in preservative treatments.

Interesting experiments on 20,000 ties to ascertain the absorptive properties were made by Mr. F. J. Angier in 1908–09 at the treating plant of the Chicago, Burlington & Quincy Railroad, using the zinc-creosote process. The results are summarized in Table 9.

Class A includes ties absorbing less than 22 percent of their volume; Class B, ties absorbing between 23 and 30 percent; Class C, ties absorbing more than 30 percent. In all cases the ties were kept in the cylinder until no more preservative could be forced into them. With hardwoods, such as oak, hickory, ash, beech, etc., the pressure was 175 pounds, but with softwoods this was reduced to from 125 to 150 pounds per square inch. In both cases the pressure was held for from 2 to 5 hours. No separation of the ties was made on the basis of their proportion of sapwood and heartwood, but about 75 percent of them were hewed.

TABLE 9.—ABSORPTION OF PRESERVATIVE BY VARIOUS SPECIES OF CROSS-TIES[1]

CLASS A

| Kind of wood | Number ties used in the tests | Absorption percent of volume | Number months seasoned in yard |
|---|---|---|---|
| Beech | 2,481 | 21.8 | 15 |
| Oak, red | 3,112 | 20.9 | 6–15 |
| Hemlock | 1,364 | 20.7 | 8–15 |
| Oak, pin | 671 | 19.5 | 10 |
| Hickory | 414 | 18.8 | 2– 8 |
| Tamarack | 2,329 | 17.1 | 6– 8 |
| Oak, white | 731 | 14.2 | 7 |
| CLASS B | | | |
| Hard maple | 691 | 28.3 | 15 |
| Popular | 1,348 | 26.8 | 7– 9 |
| Sycamore | 364 | 26.6 | 7 |
| Ash | 318 | 23.0 | 2– 6 |
| Sweet gum | 928 | 23.0 | 5– 9 |
| Chestnut | 345 | 22.6 | 12 |
| CLASS C | | | |
| Shortleaf pine | 2,192 | 36.9 | 5– 9 |
| White elm | 872 | 36.6 | 7–15 |
| Cypress, white | 662 | 35.4 | 7– 8 |
| Red elm | 626 | 34.9 | 6– 9 |
| Soft maple | 599 | 33.1 | 6 |
| Red birch | 775 | 33.0 | 6– 9 |
| Tupelo gum | 790 | 30.7 | 8 |

**Proportion of Sapwood.**—As has been stated, the sapwood of practically all woods native to the United States readily absorbs preservatives. The heartwood, however, is much more resistant, so much so in some cases that no effective treatment is possible. Two hundred maple ties thoroughly air seasoned (the moisture content ranging from 24 to 39 percent) were treated by the full-cell and Burnett processes at the U. S. Forest Products Laboratory. It was found that of the ties given a full-cell treatment, those containing 43.7 percent sapwood absorbed 10.48 pounds of creosote per cubic foot, while those containing 82.7 percent of sapwood absorbed 17.40 pounds per cubic foot. In the Burnett treatments the difference was not so pronounced. Ties containing 46.2 percent sapwood absorbed 19.7 pounds of solution,

[1] Proceedings of Wood Preserver's Assn., 1911

while those which contained 80.5 percent absorbed 22.5 pounds. Because of this difference in the absorption by sapwood and heartwood, ties which contain large amounts of sapwood should be treated separately. Differences in absorption by ties of the same species, but with varying proportions of sapwood, are often greater than in the case of widely different species. If the ties are "pole" ties, it will be found that those of certain species almost invariably fall in the same class when graded with reference to the percent of sapwood. The grouping will be approximately as shown in Table 10.

TABLE 10.—CLASSIFICATION OF POLE TIES BASED ON THEIR SAPWOOD CONTENT

| Group I Sapwood 1 inch or less in width (less than 20 per cent of volume of tie) | Group II Sapwood 1 inch to 2½ inches in width (more than 20 per-cent, but less than 50 per-cent of volume of tie) | Group III Sapwood over 3 inches wide (more than 50 percent of volume of tie) |
|---|---|---|
| Oaks. | Longleaf pine. | Shortleaf pine. |
| Douglas fir. | White pine. | Loblolly pine. |
| Cedar. | Hard maple. | Western yellow pine. |
| Chestnut. | White elm. | Cypress. |
| Tamarack. | Red elm. | Lodgepole pine. |
| Hemlock. | | Tupelo gum. |
| Spruce. | | Red gum. |
| | | Sycamore |
| | | Poplar. |
| | | Soft maple. |
| | | Red birch. |
| | | Hickory. |
| | | Ash. |
| | | Beech. |

This grouping does not, however, in all cases accurately represent the relative resistance to penetration of the various species. For example, red oak, because of its porous nature, can readily be penetrated to the center, and thus, in spite of its comparatively small amount of sapwood, would be grouped with ties of a structure resembling the elms. Also, the sapwood of soft maple, hickory, ash, and beech is more resistant to treatment than that of the other species mentioned in Group III.

If ties are cut from logs larger than 12 to 14 inches in diameter, as is usually the case with sawed ties, the percentage of sapwood may range from zero to the maximum shown in the table; hence the grouping of such ties may be different from that given. For

example, shortleaf pine ties cut with little or no sapwood would fall in Group II, hard maple without sapwood in Group I. Sapwood can be distinguished from heartwood by its difference in color, and it is as a rule easy to separate ties into groups according to their sapwood content. Such a separation will undoubtedly assist in a proper grouping of ties for treatment, but before this grouping can definitely be decided upon as the best, considerably more experimenting will be necessary.

**Moisture Content.**—When ties are green the cell walls and many of the cell spaces are filled with water. To properly inject a preservative, at least a part of this water must be removed, and the extent to which it has been removed governs the amount of preservative which can be injected. It is important, therefore, that all of the ties to be treated at one time should have approximately the same moisture content. One of the most practical ways of insuring this is to pile the ties in the yard and thoroughly air-season them.

The conditions under which ties season effect the uniformity of the treatment. Ties seasoned too rapidly are likely to "caseharden," which makes them more difficult to impregnate and affects their strength. Moreover, whether ties are seasoned with the bark on or off affects the treatment. It is good practice to season all ties to be treated in one charge under the same conditions.

**Cutting Season.**—The time of year the ties are cut also affects the uniformity and degree of treatment. Several tramloads of hemlock ties cut in the summer, fall, and winter were first air-seasoned and then treated with zinc chloride, with the results shown in Table 11.

TABLE 11.—EFFECT OF THE SEASON OF CUTTING ON THE ABSORPTION OF PRESERVATIVE

| | Weight per cubic foot before treatment | Average absorption of solution per cubic foot |
|---|---|---|
| | Pounds | Pounds |
| Summer | 33.4 | 12.9 |
| Fall | 36.2 | 10.0 |
| Winter | 37.3 | 8.9 |

It is probably safe to say that, aside from moisture content and case-hardening, the effect of the time of cutting on the penetration and absorption of preservative can be neglected in commercial

work. Good practice consists in cutting all ties in winter or late fall whenever possible.

**Conditions of Growth.**—The arrangement of the cells in the same species of wood grown under different conditions may differ to such an extent as to cause variability in the results of the treatment. When that is the case, the ties should be grouped separately. For example, a plant receiving red oak ties from the South may find it advantageous to group them separately from those received from the North. Moreover, ties cut from various parts of the tree treat differently.

Although the above considerations sound very complicated, they are not difficult of practical execution. It goes without saying that the careful grouping of ties for treatment costs more than not grouping them, but there is no doubt but what it will far more than pay in the long run. This is particularly true for treatments with creosote where the amount of preservative forced into the ties is not the maximum amount they will absorb but the amount called for by the specification. Grouping is least essential when the ties are impregnated with a solution of zinc chloride, which can be forced into them until there is no more absorbed or until the point of refusal is reached.

**Protection from Abrasion.**—It has been estimated that from 10 to 75 percent of unprotected ties fail by rail and spike cutting;[1] the former figure referring to hard, quick-decaying ties like maple, the latter to durable, soft ties like cedar. Since the number of treated ties is increasing annually, this percentage will also increase rapidly unless improved methods of fastening rails are generally adopted. Already the amount of preservative injected into ties is in some cases reduced because it is claimed to be more than is necessary to prevent decay throughout their mechanical life. With increased mechanical life of the tie the efficiency of the preservative treatment may also be increased.

The most practical means of reducing the mechanical destruction of ties are through the use of tie-plates and improved forms of spikes.

**Tie-Plates.**—Tie-plates are designed primarily to (1) distribute the impact and compression of trains over the tie; and (2) absorb the grinding action of the rail.

If the tie-plate is too light it will soon buckle, or if its bearing surface is too small it will become embedded in the tie. In

[1] Proceedings A. R. E. and M. of W. Association, Vol. 9, 1908.

either case the value of the plate is reduced. It is essential, therefore, to use plates that are strong enough to stand the pressure exerted on them, and that have sufficient surface area to properly distribute the load. Failure to meet these conditions will almost invariably result in severe mechanical wear on the tie. This is shown in Plate III, Fig. A.

Many forms of tie-plates are now on the market, but in general plates may be divided into two groups:[1] (1) Pronged or ridged plates; (2) flat plates.

In the opinion of some engineers the tie-plates should be so firmly fastened to the tie that they really become part of it. To secure this condition, the bottom of the plate is pronged, ridged, or flanged. (See Plate XIV, Fig. D.) Plates of this type were used in test ties on the Northern Pacific and Chicago and Northwestern experimental tracks laid in cooperation with the U. S. Forest Service. Although they have not been in service long enough to show their real worth, the following points were observed during recent inspections. When the plates are heavily ridged, it takes a very heavy load to embed the ridges and bring the plates down flush with the tie. In the Chicago and Northwestern track, even after 2 years' service, the majority of the ridged plates were elevated about 1/4 inch above the tie. This was due in part to the resistance offered by the ridges to embedment in the wood and in part to sand and gravel which collected under the plate; also, to the fact that the traffic over this portion of the track is now very light. After these plates become firmly embedded they have a tendency to split open the ties, and thus not only weaken them, but furnish catch basins for the retention of rain water. In ties which are difficult to impregnate with preservatives, these checks may extend beyond the zone of treated wood and thus expose the untreated interior of the tie to decay. Another char-

[1] Wooden plates have also been used experimentally, and are being tested by the U. S. Forest Service in both the Chicago and Northwestern and Northern Pacific tracks. The plates are made of creosoted oak and maple, about five-eighths of an inch thick, 8 inches long, and as wide as the base of the rail. They are inserted between the tie and the rail without any previous adzing, the common practice abroad. The results thus far have been that the plates split badly, and at times have become loose or displaced. In some cases they have embedded themselves into the ties. This is shown in Plate XIV, Fig. C. Although the tests with wooden plates have not as yet been completed, the results thus far secured have not been satisfactory. It is thought, however, that this is largely due to the poor manner in which they were placed.

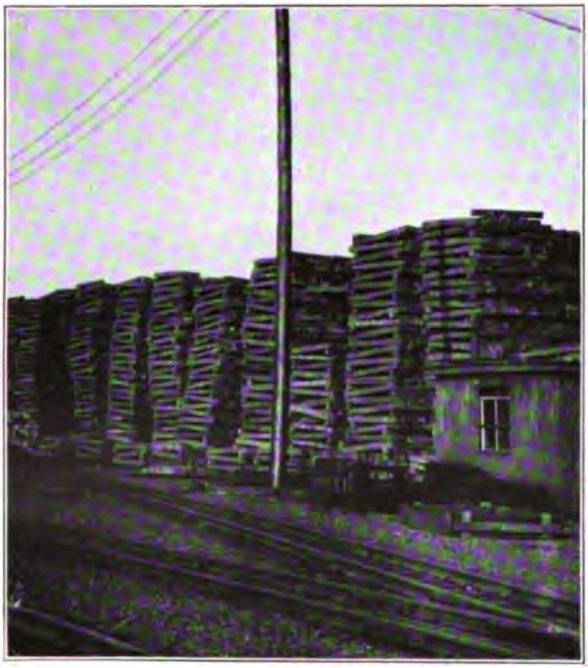

FIG. A.—A good method of piling ties for air seasoning, Port Reading Creosoting Co. (Forest Service photo.)

FIG. B.—White-oak ties seasoned too fast. (Forest Service photo.)

(Facing page 142.)

Plate XIV

Fig. C.—Ties "protected" with wooden plates. Note plate crushed into tie. (Forest Service photo.)


Fig. D.—Metal tie plate. (Courtesy Spencer-Otis Mfg. Co.)

acteristic of such plates is to grind into the wood fibers, especially of softwood ties such as loblolly pine, cedar, etc. This action also may extend beyond the treated portions of the tie and cause interior rot. These features are unquestionably objectionable, and in some cases may prove of such a serious nature that they will overbalance the good points, such as adherence to the tie and lack of rattling, claimed for plates of this type.

The objectionable features of pronged or flanged plates are obviated if they are made flat and so rest flush on the surface of the tie. The chief objections to this type seem to be the rattling noise which they make when they are not firmly held to the spikes, and the fact that all resistance to creeping and lateral thrust must be borne entirely by the spikes. The rattling, however, would seem to be an excellent indication that the spikes are loose and need attention. Just how much weight must be attached to the second objection cannot at this time be ascertained from the plates under observation by the U. S. Forest Service. Thus far no creeping or widening of the gauge of the experimental track has been noticed.

It seems, moreover, in view of the data thus far secured, that of the various forms of tie-plates now under test, those made of metal with a flat bearing surface, or the bearing surface only slightly ridged, are giving better service in protecting the ties from mechanical destruction than those made of metal heavily flanged or pronged.

A feature which is not a present taken into account, but which unquestionably will be, is the size of tie-plate to be used on different kinds of wood. A softwood tie like loblolly pine is more subject to rail cutting than a hardwood tie like oak, and consequently needs a larger tie-plate for its protection. Some tests at the U. S. Forest Products Laboratory of compressive strength of various kinds of ties gave results as shown in Table 12 on pages 144 and 145.

In other words, shortleaf pine is only about half as strong as red oak and consequently needs a plate with a considerably larger area in order properly to distribute the load.

**Spikes.**—The practice of spiking ties to the rail has long been recognized as capable of improvement. The spikes, especially in softwood ties, do not hold firmly, and permit the rail to "creep" and "pump," thus greatly shortening the life of the tie. Furthermore, they tear the wood-fibers, work loose, and permit rain

TABLE 12.—CRUSHING STRENGTH OF CROSS-TIES IN PERCENT OF WHITE OAK

| Kind of tie | | Fiber stress at elastic limit perpendicular, to grain, lb. per sq. in. | Fiber stress in percent of white oak, or 853 lb. per sq. in. |
|---|---|---|---|
| Common name | Botanical name | | |
| Osage orange | Toxylon pomiferum | 2,260 | 265.0 |
| Honey locust | Gleditsia triacanthos | 1,684 | 197.5 |
| Black locust | Robinia pseudacacia | 1,426 | 167.2 |
| Post oak | Quercus minor | 1,148 | 134.6 |
| Pignut hickory | Hicoria glabra | 1,142 | 133.9 |
| Water hickory | Hicoria aquatica | 1,088 | 127.5 |
| Shagbark hickory | Hicoria ovata | 1,070 | 125.5 |
| Mockernut hickory | Hicoria alba | 1,012 | 118.6 |
| Big shellbark hickory | Hicoria laciniosa | 997 | 116.9 |
| Bitternut hickory | Hicoria minima | 986 | 115.7 |
| Nutmeg hickory | Hicoria myristicaeformis | 938 | 110.0 |
| Yellow oak | Quercus velutina | 857 | 100.5 |
| White oak | Quercus alba | 853 | 100.0 |
| Bur oak | Quercus macrocarpa | 836 | 98.0 |
| White ash | Fraxinus americana | 828 | 97.1 |
| Red oak | Quercus rubera | 778 | 91.2 |
| Sugar maple | Acer saccharum | 742 | 87.0 |
| Rock elm | Ulmus | 696 | 81.6 |
| Beech | Fagus atropunicea | 607 | 71.2 |
| Slippery elm | Ulmus pubescens | 599 | 70.2 |
| Redwood | Sequoia sempervirens | 578 | 67.8 |
| Bald cypress | Taxodium distichum | 548 | 64.3 |
| Red maple | Acer rubrum | 531 | 62.3 |
| Hackberry | Celtis occidentalis | 525 | 61.6 |
| Incense cedar | Libocedrus decurrens | 518 | 60.8 |
| Hemlock | Tsuga canadensis | 497 | 58.3 |
| Longleaf pine | Pinus palustris | 491 | 57.6 |
| Tamarack | Larix lariciana | 480 | 56.3 |
| Silver maple | Acer saccharinum | 456 | 53.5 |
| Yellow birch | Betula Lutea | 454 | 53.2 |
| Tupelo | Nyssa aquatica | 451 | 52.9 |
| Black cherry | Prunus serotina | 444 | 52.1 |
| Sycamore | Platanus occidentalis | 433 | 50.8 |
| Douglas fir | Pseudotsuga taxifolia | 427 | 50.1 |
| Cucumber tree | Magnolia acuminata | 408 | 47.8 |
| Shortleaf pine | Pinus echinata | 400 | 46.9 |
| Red pine | Pinus resinosa | 358 | 42.0 |
| Sugar pine | Pinus lambertiana | 353 | 41.4 |
| White elm | Ulmus americana | 351 | 41.2 |
| Western yellow pine | Pinus ponderosa | 348 | 40.8 |

TABLE 12.—CRUSHING STRENGTH OF CROSS-TIES IN PERCENT OF WHITE OAK.—*Continued.*

| Kind of tie | | Fiber stress at elastic limit perpendiculaa, to grain, lbs. per sq. in. | Fiber stress in percent of white oak, or 853 lb. per sq. in. |
|---|---|---|---|
| Common name | Botanical name | | |
| Lodgepole pine | Pinus contorta | 348 | 40.8 |
| Red spruce | Picea rubens | 345 | 40.5 |
| White pine | Pinus strobus | 314 | 36.8 |
| Engelmann spruce | Picea engelmanni | 290 | 34.0 |
| Arborvitæ | Thuja occidentalis | 288 | 33.8 |
| Largetooth aspen | Populus grandidentata | 269 | 31.5 |
| White spruce | Picea canadensis | 262 | 30.7 |
| Butternut | Juglans cinerea | 258 | 30.3 |
| Buckeye (yellow) | Aesculus octandra | 210 | 24.6 |
| Basswood | Tilia americana | 209 | 24.5 |
| Black willow | Salix nigra | 193 | 22.6 |

to collect and decay to start. This necessitates a rather frequent respiking of the rail, which often fills the tie with holes to such an extent that it is "spiked to death" and must be removed. It was thought that by first boring a hole into the tie and then driving the spike into it, the fibers would not be torn and then the spike would hold more firmly. (See Plate XII, Fig. C.) Tests were made[1] in which ordinary 9/16-inch square spikes were driven into red-oak ties previously bored with holes 3/8, 7/16, and 1/2 inches in diameter. Although the spikes were driven by an experienced trackman, in over half the cases they failed to follow the holes. Their resistance to pulling was thus reduced. When no hole was bored the average force required to pull the spikes was 8827 pounds; when bored in the manner above described the respective forces were 8050, 8106, and 7154 pounds. In order to overcome the objection mentioned the spikes were pointed on four sides, and when this was done there was no difficulty whatever in getting them to follow the holes. Furthermore, their resistance to vertical pull was increased and the wood-fibers were not seriously torn. The number of pounds required to pull pikes from red-oak ties was as follows:[2]

[1] By J. A. Newlin, in charge of timber tests, Forest Products Laboratory.

[2] It will be noticed that the spikes driven in the first test held more firmly than those driven in the second. For example, when no hole was bored it took 8827 pounds to pull them in the first test and only 7613 pounds in the

| | Pounds |
|---|---|
| Ordinary 9/16-inch square spikes driven without boring.......... | 7613 |
| Ordinary 9/16-inch square spikes pointed on four sides, driven in hole 3/8 inch in diameter.................................. | 8178 |
| Ordinary 9/16-inch square spike pointed on four sides, driven in hole 7/16 inch in diameter................................ | 7856 |
| Ordinary 9/16-inch square spike pointed on four sides, driven in hole 1/2 inch in diameter.................................. | 7664 |

When the diamond-pointed spikes were driven into the tie without first boring holes, the ties were almost invariably split. It appears, therefore, that they cannot be used satisfactorily without previous boring.

Some of the ties used in these tests were treated with creosote, others with zinc chloride, and still others were left untreated, but no appreciable difference due to treatment was noticed. In a few cases a heavy oil was poured into the holes and allowed to soak for 16 hours before the spikes were driven. The resistance to pull was decreased from 7644 to 6628 pounds. While no tests were made, it is quite possible that if the holes are bored into the ties before they are treated the resistance of the spike will be less than if they are bored after treating. In spite of this, however, it is believed that if holes are bored at all they should be bored before and not after treatment, since in the former case the ties will be fully protected against rot.

While the tests described show that boring holes into ties previous to spiking them is an improvement over the common practice in this country, experience abroad leads to the conclusion that even better results can be obtained by the use of screw spikes. To secure data for American operating conditions, screw spikes were used by the U. S. Forest Service in the Northern Pacific, Chicago & Northwestern, and Chicago, Milwaukee & St. Paul test tracks. In laying the Northern Pacific and Chicago & Northwestern tracks no screw-spike boring or driving machine was available, so that the holes had to be bored and the spikes inserted by hand. In some cases the holes were not bored deep enough, and the point of the spike struck the base of the hole. On further tightening the spike the threads in the wood were destroyed. Furthermore, the holes were not in all cases bored

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second. This cannot be attributed to any difference in the spikes, but to the ties into which they were driven. Also, in the latter case the spikes were pulled soon after they were driven. The two series of tests, therefore, are not comparable with each other.

vertically, so that the spikes were inserted at various angles. When the Chicago, Milwaukee & St. Paul track was put in place, a screw-spike boring and driving machine was used, and the difficulties previously encountered were done away with. The machine drove the holes vertically and to a uniform depth, so that the spikes all had proper alignment and clearance. In every case the machine drove the spikes firmly into the tie.

The screw spikes used in the Northern Pacific and Chicago & Northwestern test tracks were driven through plates which did not reenforce the head of the spike against lateral thrust. After 3 years' service many of the these spikes were badly bent, resulting in a widening of the track gauge. In laying the Chicago, Milwaukee & St. Paul track, a plate with bosses for supporting the heads of the spikes was used, which it is believed will materially increase their holding power.

In a large number of tests made at Purdue University, a part of which were conducted by the U. S. Forest Service,[1] it was found that screw spikes had from 1.7 to 3.8 times the strength of the common spike against pull, and from 1.2 to 2.4 times the lateral resistance of the common spike. The heads of the spikes were not supported in these tests.

An objection raised against the use of screw spikes is that it takes longer to insert them than to insert cut spikes, and that this at times delays the passage of fast trains. In laying the Chicago, Milwaukee & St. Paul test track this objection was partially overcome by spiking every third tie throughout the rail length, which permitted trains to pass, and afterward spiking the remaining ties.

A further objection to the use of screw spikes is the difficulty of regauging the track when the rail becomes worn. It is possible that this objection may in time be overcome by altering the design of plates used with this type of spike.

While the use of screw spikes in this country is still in its infancy and final judgment cannot as yet be pronounced, it gives promise of overcoming the objections raised against the ordinary cut spike. If it succeeds in this it will unquestionably result in greatly reducing the mechanical destruction of ties.

**Adzing and Boring Ties.**—In Chapter VII it was stated that adzing and boring ties prior to treatment was good practice, and

[1] Fourth Progress Report of Tests on Treated Ties, by W. K. Hatt, Purdue University, Bulletin 124, A. R. E. and M. of W. Assn.

the data given above show how the holding power of spikes can be increased by driving them through such holes. Of equal importance is a proper bearing of the rail or plate on the tie, for if this is not done the wear will be concentrated over a small area and the mechanical destruction of the tie hastened. Furthermore, it is felt that the unequal bearing of rails on ties can be held responsible, in part at least, for breaking the rail, especially during cold weather. Adzing prior to treatment not only enables the plate and rail to be firmly and uniformly fastened to the tie, but makes it possible to at least coat with preservative that portion of the tie most subject to wear. For these reasons adzing and boring of ties are highly commended.

**The Selection of Processes for Treating Ties.**—The wide range of conditions under which cross-ties are used makes a selection of treating processes necessary if most economic results are to be secured. Lack of specific data on the exact value of the various processes prevents a clear-cut decision as to which is best for a given set of requirements.

The ideal treatment is one in which the ties fail from decay and wear at the same time. If the failures are caused by decay, then a more efficient preservative should be used; if, on the other hand, the failures are caused by wear which cannot be prevented, then a less efficient treatment should be used. It can be readily seen that any process which puts into ties more preservative than is necessary to protect them longer than their mechanical life is a wasteful process, because after the ties are removed from the track the preservative in them is useless. The proper balance between the failure of a tie from decay and from wear is a very difficult one to obtain with our present limited fund of data and this complicates greatly the selection of a proper treating process. Certain general rules can, however, be laid down which should aid in selecting the proper process for any given conditions. The most important points to consider in this connection are: (1) kind and form of ties to be used, (2) the tonnage over the road, (3) climatic conditions, and (4) type of track construction. These are so closely interwoven that they must all be considered together.

If the road is so fortunate as to run through or tap a forested region containing strong, durable tie material, the need of a preservative treatment is not pressing and may even be dispensed with entirely. Thus, if ties of heart cypress, redwood, and cedar

can be obtained at a reasonable price, no treatment other than a protection from wear is required. However, this condition rarely exists, so that some method of increasing the resistance of the wood to decay becomes necessary. If the wood is refractory—that is, if a preservative cannot be forced into it except superficially—as with Douglas fir, tamarack, etc., as heavy a treatment as possible with straight creosote will probably give most efficient results because even at best only small amounts of the oil will be absorbed. If, however, the wood is porous and readily absorbs preservative, then some cheaper process, like the Burnett, Card, or empty-cell creosote is preferable. The same is true for those ties which are cut so as to have fairly wide strips of sapwood on one or both sides while the faces are of resistant heartwood possessing in itself little durability.

Obviously, ties which have a heavy tonnage passing over them are more subject to failure from wear than ties laid in a track where the tonnage is light. In general, such ties should be given a less efficient and expensive treatment, for if heavy injections are made, considerable quantities of preservative will be destroyed with the ties.

Climatic conditions must be carefully considered. Ties laid in regions of heavy rainfall had best be treated with straight creosote. In arid regions and where rainfall is comparatively light, zinc-treated ties may be advantageously used.

The type of track construction has much to do with the selection of the process. In general, best construction enables the use of the more effective and expensive treating processes. For example, a track laid with heavy rail, heavy tie plates, screw spikes and a firm rock ballast would call for a more costly and effective treating process than one laid with cut spikes, dirt ballast, and no tie plates. It should not follow that this is universally true. Suppose, for instance, that the track construction is of the best, but that the ties are of a comparatively soft wood like loblolly pine; it is the author's opinion that an empty-cell process should be selected in preference to a full-cell, as it would give an equal length of life to the tie with a much less consumption of preservative, and hence the expense would be less. As mentioned above, a decision on the selection of a proper timber-treating process for ties can be correctly made only after all factors affecting the life of the tie have been considered. It appears, therefore, that railroads controlling a large mileage, especially,

if it traverses a wide territory, should use more than one process in order to secure most economic returns. In the above discussion, the question of initial cost has not been mentioned, as its effect in the selection of a process is so obvious as to need no special comment. The ideal process selected may be the cheapest process—Burnettizing, for example—in so far as initial cost is concerned. Or the ideal process may be the most expensive—full-cell creosote—in which case, if the company could not afford it, the next best rather than none at all should be selected. A common feature is that practically all standard processes using pressure pay if compared to the use of untreated ties, so the problem reduces itself largely to a question of which pays best.

**Cost of Treating Ties.**—The total cost of treating ties can be divided into the following general items: (1) seasoning, (2) labor, (3) fuel, (4) plant operation and maintenance, and (5) chemicals.

The majority of ties now treated in the United States are air-seasoned prior to treatment. The cost of this varies with the kind of wood, season of the year, and geographical location. In general, however, seasoning charges range from about 0.50 to 1.5 cents per tie.

Labor includes all forms necessary to the treatment, such as loading and unloading of ties in the yard, and for the tie plant and superintendence. It also varies considerably, but ranges from about 3 to 6 cents per tie.

Fuel is least in those plants which can use natural gas or oil and highest in those most remote from a source of supply, but ranges from about 1/2 to 2 cents per tie.

On account of the corrosive action of zinc chloride, the life of a plant using that kind of a preservative is usually reckoned as shorter than that of one using creosote; consequently, its depreciation is greater. If the capacity of the plant is lowered through accident, shortage of ties, etc., the depreciation charges per tie will be very high. The total cost of maintenance, including this depreciation, interest on the investment, etc., will usually range from 1 to 2 cents per tie.

Practically all of the ties now treated in commercial plants in the United States are injected with zinc chloride or with creosote, either alone or in combination. Only a few plants use preservatives like crude oil and mercuric chloride. It is customary to inject about 1/2 pound of dry zinc chloride per cubic foot of wood although this varies at times from one-third to two-

thirds of a pound. This salt costs from 3 1/2 to 5 cents per pound. Creosote costs from about 7 to 12 cents per gallon in large quantities. It is customary in tie work to inject from 5 to 10 pounds of this oil per cubic foot.

With the above data the cost of tie treatments may be estimated. It should be borne in mind, however, that the figures given are general, and will not apply to all conditions. Using them as a basis, however, the cost of treating a standard 7 inch × 9 inch × 8 foot tie will be approximately as shown in Table 13, royalties not included. It is understood that royalties are now charged in the Rueping and Card processes, while the Lowry process is operated under certain restrictions by the company which controls the Lowry patents. For the other processes listed in the table no royalties are required.

TABLE 13.—APPROXIMATE COST OF TREATING TIES

(Tie 7 inches × 9 inches × 8 feet)

| Process | Cost per tie, cents |
|---|---|
| Burnett | 10–14 |
| Wellhouse | 12–16 |
| Card | 16–20 |
| Rueping(*a*) | 25–29 |
| Lowry(*b*) | 32–35 |
| Full-cell cresote(*c*) | 39–45 |

*a* = assuming about 6 pounds of creosote per cubic foot absorption.
*b* = assuming about 8 pounds of creosote per cubic foot absorption.
*c* = assuming about 10 pounds of creosote per cubic foot absorption.
Assuming creosote costs about 1 cent per pound and zinc chloride about 4 cents per pound.

It will be noted in this table that the cost of the preservative used is a large percentage of the total cost of treatment. Creosote, for example, greatly increases the cost of the treatment and when it is used in comparatively large quantities—8 pounds or over per cubic foot—all other costs make but a small fraction in the total cost of treatment. The opportunity either for an efficient preservative at lower cost or for some modified method of operation which will enable a high-priced preservative to be better utilized than is being done in present practice is strikingly apparent.

**Economy in Treating Ties.**—There is no longer any just doubt but what the preservative treatment of ties pays. Unfortunately,

reliable records on the life of treated ties which have been in service for long periods are too meager to enable exact estimates of actual economy to be made, so that the financial saving is still a matter of conjecture. Because of this condition it is not possible to state what process of treatment is most economical, and it will take several years before any true basis for such statements will be warranted. As has already been pointed out, it is quite likely that the different methods of treatment now practised will be found to have rather sharp limitations so that they will not overlap and compete to such a large degree as at present. The different kinds of ties, the different types of construction, and the different geographical regions traversed by our roads will demand different treatments.

In the meantime, the best that can be done is to use what data is already available on treated and untreated ties in service, and add to this our knowledge on the efficiency of the various preservatives used, the action of wood-destroying fungi, and the durability and susceptibility to treatment of the various woods now used for manufacture into ties.

While the saving in money is undoubtedly the most important feature which the railroads will consider, nevertheless it is believed that other factors should not be overlooked. If a process showing lowest annual charges is selected, it may be it does not prolong the life of the ties as much as some other process having higher annual charges. This means that tie removals will be more frequent and the roadbed will consequently be more continuously disturbed. The disadvantages are obvious. Furthermore, if the price of untreated ties shows a steady advance, the advantage of securing as long a life as possible from them is readily apparent.

Because of the many factors which influence the economy resulting from treating ties and because of the uncertainty of present data on the durability of ties, estimates on saving are here given for only two processes—the Burnett and full-cell creosote—as these represent the probable extremes, certainly in so far as initial cost is concerned. In order to make the results comparable, it is assumed that all ties are plated, the plates costing 25 cents per tie, and that the cost of placing the ties in the track is 15 cents. Furthermore, all ties are subjected to the same traffic conditions and preliminary treatment. As annual charges best show resulting economy they are used in the following table

TABLE 14.—ESTIMATED ANNUAL SAVING DUE TO THE TREATMENT OF CROSS-TIES WITH PRESERVATIVES AND THE USE OF TIE PLATES. (TIES 7 INCHES × 9 INCHES × 8 FEET.)

(In each case a charge of 25 cents per tie for tie plates and 15 cents for placement has been added to the cost of the tie, and included in the computed annual charge. Cost of Burnettizing, 12 cents per tie—cost of full-cell creosote 42 cents per tie.)

| | Estimated life | | | Cost of ties | | | Annual charge in track | | | Annual saving of treat treate over untreated ties | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Treated | | | Treated | | | Treated | | | |
| | Un-treated | 10 lb. creosote per cu ft. | ½ lb. ZnCl₂ per cu. ft. Burnett process | Un-treated | 10 lb. creosote per cu. ft. | ½ lb. ZnCl₂ per cu. ft. Burnett process | Un-treated | 10 lb. creosote per cu. ft. | ½ lb. ZnCl₂ per cu. ft. Burnett process | 10 lb. creosote per cu. ft. | ½ lb. ZnCl₂ per cu. ft. Burnett process |
| | Years | Years | Years | | | | | | | | |
| Black locust | 20 | ........ | ........ | \$0.60[1] | ........ | ........ | \$0.080 | ........ | ........ | ........ | ........ |
| Redwood | 12 | ........ | ........ | 0.53 | ........ | ........ | 0.104 | ........ | ........ | ........ | ........ |
| Cedar | 11 | ........ | ........ | 0.46 | ........ | ........ | 0.103 | ........ | ........ | ........ | ........ |
| Cypress | 10 | ........ | ........ | 0.41 | ........ | ........ | 0.104 | ........ | ........ | ........ | ........ |
| White oaks | 8 | ........ | ........ | 0.60[1] | ........ | ........ | 0.155 | ........ | ........ | ........ | ........ |
| Longleaf pine | 7 | 20 | 11 | 0.52[2] | \$0.94 | \$0.64 | 0.159 | \$0.108 | \$0.124 | \$0.051 | \$0.035 |
| Chestnut | 7 | 15 | 11 | 0.44 | 0.86 | 0.56 | 0.145 | 0.13 | 0.12 | 0.015 | 0.025 |
| Douglas fir | 6 | 15 | 11 | 0.41 | 0.83 | 0.53 | 0.160 | 0.12 | 0.11 | 0.040 | 0.05 |
| Spruce | 6 | 14 | 10 | 0.49 | 0.91 | 0.61 | 0.175 | 0.13 | 0.13 | 0.045 | 0.045 |
| Western pine | 5 | 17 | 12 | 0.53 | 0.95 | 0.65 | 0.215 | 0.118 | 0.117 | 0.097 | 0.098 |
| White pine | 5 | 14 | 10 | 0.43 | 0.87 | 0.55 | 0.192 | 0.130 | 0.127 | 0.062 | 0.065 |
| Lodgepole pine | 5 | 16 | 11 | 0.46 | 0.88 | 0.58 | 0.199 | 0.117 | 0.117 | 0.082 | 0.082 |
| Tamarack | 5 | 15 | 10 | 0.41 | 0.83 | 0.53 | 0.187 | 0.123 | 0.120 | 0.064 | 0.067 |
| Hemlock | 5 | 15 | 10 | 0.33 | 0.75 | 0.45 | 0.169 | 0.115 | 0.120 | 0.054 | 0.049 |
| Red oaks | 4 | 20 | 12 | 0.45[2] | 0.87 | 0.57 | 0.240 | 0.101 | 0.108 | 0.139 | 0.132 |
| Beech | 4 | 20 | 12 | 0.36 | 0.78 | 0.48 | 0.214 | 0.094 | 0.098 | 0.120 | 0.116 |
| Maple | 4 | 18 | 12 | 0.45[2] | 0.87 | 0.57 | 0.240 | 0.107 | 0.108 | 0.033 | 0.032 |
| Gum (tupelo) | 3 | 15 | 9 | 0.52 | 0.94 | 0.64 | 0.338 | 0.134 | 0.146 | 0.204 | 0.192 |
| Elm | 5 | 20 | 12 | 0.45[2] | 0.87 | 0.57 | 0.196 | 0.101 | 0.108 | 0.095 | 0.088 |
| Shortleaf pine | 3 | 15 | 9 | 0.35[2] | 0.77 | 0.47 | 0.275 | 0.112 | 0.122 | 0.163 | 0.153 |
| Loblolly pine | 2 | 15 | 9 | 0.32[2] | 0.74 | 0.44 | 0.381 | 0.109 | 0.118 | 0.227 | 0.263 |
| Sycamore | 4 | 15 | 9 | 0.45[2] | 0.87 | 0.57 | 0.239 | 0.127 | 0.136 | 0.112 | 0.103 |

[1] Prices from the Bureau of Census; subject of course to variation.

[2] Prices quoted based on general observations; also subject to variation.

and are figured on the cost of the ties in the track, the computation being made by the following formula:

$$r = R\,\frac{1.0p^n.0.0p}{1.0p^n - 1}$$

Where $r$ = equivalent annual charge.
$R$ = initial expenditure.
$p$ = rate of interest (taken as 5 percent).
$n$ = term of years.

It will be noted that, in general, the ties treated with creosote show a slightly greater economy than when treated with zinc chloride. In this connection, however, the remarks already made concerning the selection of the treating process should be kept in mind; that is, ties treated with zinc chloride should not be laid in wet localities. If ties treated by this method are laid in such regions the differences shown in the table would, of course, be considerably greater.

It should be noted that greatest economy in treating ties comes from those which possess little durability in an untreated condition, this amounting in certain cases to an annual saving of over 20 cents per tie per year. Least saving comes from ties which are resistant to treatment and which do not possess a marked natural durability. Such ties ought not to command high prices. In fact, it is exceedingly likely that the prices now paid for ties will be readjusted as reliable data on their serviceability is gradually obtained, and more value is placed upon their intrinsic properties. Red oak, beech, and elm, for example, will become more and more prized as good tie woods, because of their rapid growth, hardness, and permeability.

If the figures given in the table are found by actual experience to be accurate, the difference in the annual saving between the two processes compared is insignificant. This does not mean, however, that the selection of the process is unimportant, because other factors such as initial cost, ultimate length of service, local climatic conditions, etc., as pointed out above, must also be taken into consideration.

**Need for Test Tracks.**—It is apparent from the above discussion on the economy of treatment that little of definite value on the efficiency of various processes can be determined until accurate data is available. Without doubt, the best way of securing such data is to set aside certain portions of the main track,

typifying conditions of the road, for experimental or test purposes. Such portions of the track are called "test or experimental tracks." In them complete records should be kept on each tie, such as kind of wood, how treated, when and how laid, and notes on its character of failure obtained from yearly inspections. In addition, general data on the character of the ballast, type of construction, tonnage over the road, etc., should be made a matter of record. To assist in identifying the ties, each tie should have zinc-coated dating nails driven into it at some readily accessible point. A good place for the nails is about 1 foot inside the rail.

The old method of driving dating nails into all treated ties and attempting to keep records on all of them has not proved successful and is not recommended. Trackmen as a rule will not keep accurate records and unless the records are accurate they are worse than useless, as they may lead to absurd conclusions. The direct and positive value of the data secured from test tracks enables accurate deductions to be made of the efficiency of the treatment and far more than justifies the cost of placing and maintaining them.

# CHAPTER IX

## PROLONGING THE LIFE OF POLES AND CROSS ARMS FROM DECAY AND INSECTS

### POLES

**Selection of Species.**—According to present usage, in order to make a satisfactory pole, a tree must have the following general properties: Its wood must be strong, comparatively light in weight and durable, its taper must be gradual and well defined, its form must be straight, and in addition its supply must be accessible and abundant. These requirements necessarily restrict the number of species which can be used. For example, of the 3,000,000 poles consumed annually in the United States, over two-thirds are cedar and about one-seventh chestnut. Hence, over 80 percent are cut from only two kinds of wood.

If the preservative treatment of poles was more generally practised, a much larger variety of woods could be drawn upon, since they possess all of the requisite properties save durability. It seems apparent, therefore, that as the present supply of "pole woods" becomes more and more exhausted the need for preservative treatment will increase. Such woods as the pines, spruces, and firs should prove admirably adapted for poles, and they will undoubtedly be called into use. In fact, a movement in this direction has already taken place, and poles cut from these timbers are now being used in several places in the West.

Insects, in addition to decay, also attack poles, thus weakening them not only by their burrows but also by admitting channels through which the decay can enter and spread. As the methods which prevent decay will also prevent insect attack, the two are discussed in common in this chapter.

**Manufacture of Poles.**—Most of the poles used in the United States are simply tree trunks which have been trimmed of limbs and then peeled. Very few sawed poles are used. As has already been pointed out (Chapter IV) the best time to cut timber is in winter or late fall. Poles cut during this period are, however, more difficult to peel, as the bark clings tenaciously to them,

whereas in spring long strips of bark can readily be torn from the trunk. It is very important to peel all bark from that portion of the pole to be treated; otherwise the bark will prevent a uniform penetration of the preservative.

The practice of dragging poles over the ground for long distances, thereby grinding off the outer layers of wood, should be prohibited, as it not only weakens the pole but makes it more susceptible to decay.

It is also bad practice to saw that portion of the pole which projects above ground, leaving the butt the natural shape and size of the tree, unless the butt is given a thorough preservative treatment, because the sap on the butt will quickly decay and infect the heartwood. If sawing must be done on account of local or other requirements, it is better to saw the entire pole. As a general proposition, however, sawing should be avoided if possible. The top of the pole should also be cut slanting unless there is some reason why this cannot be done. If a plate or cap is placed on the top of the pole, the wood underneath should be at least brush treated with creosote. Whenever possible the pole should be trimmed and bored to exact dimensions before it is treated, in order to avoid cutting into the treated wood and thus exposing the untreated interior.

**Method of Seasoning.**—Common practice now pays little attention to seasoning poles. (See Plate XV, Fig. A.) Poles are generally piled one on top of the other in order to occupy as little space as possible. If the poles are not to be treated and if they are not held too long in these piles so that decay will attack them, no serious objection can be levied against this practice. Of course, when piled in this manner, the rate at which they lose water is greatly decreased and consequently they will weigh more when shipped; hence, the cost of transportation is increased.

If the poles are to be treated, especially by the open-tank or brush methods, a preliminary air seasoning is highly desirable. The best way to do this is to roll the poles on skids with sufficient space between them so that the air can circulate freely. These skids can be built of poles placed horizontally and elevated a foot or more above the ground. If space permits, but one layer of poles should be built on each skid, but if necessary, several layers can be piled on each other. (See Plate XV, Fig. B.)

Factors other than ease of handling should be given con-

sideration in selecting the seasoning yard. For example, the ground should be fairly level, well drained, and as free from weeds and decayed wood as possible. The poles should be exposed to the sun and air currents so that the seasoning will be rapid. Too rapid seasoning, however, may check the poles, in which case they can be piled closer together. Incipient checks, which are liable to increase in size, should be protected with "S-irons" (Fig. 22).

The length of time poles should be seasoned varies primarily with the time of year, the kind of wood, and climatic conditions.

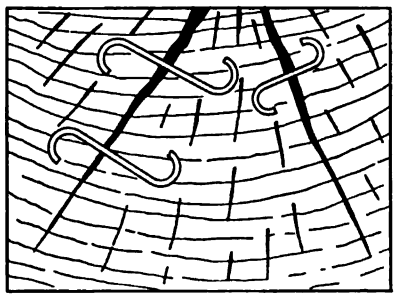

Fig. 22.—Method of applying "S"-irons to prevent checking.

From a large number of tests made by the U. S. Forest Service in cooperation with the American Telephone and Telegraph Company the following table has been compiled:

Table 15.—Approximate Time Required to Air Season Poles for Treatment

| Species | Region | No. of months required when poles are cut in | | | |
|---|---|---|---|---|---|
| | | Spring | Summer | Autumn | Winter |
| Chestnut............... | Maryland..... | 3 | 3 | 7 | 6 |
| Southern white cedar.... | Carolinas..... | 2 | 2 | 4 | 3 |
| Northern white cedar.... | Michigan..... | 5 | 5 | 9 | 8 |
| Western yellow pine..... | California..... | 5 | 2 | 9 | 6 |

The above figures may be used to predict the seasoning periods for other varieties of wood not listed, although just how accurate they will be cannot be told except by actual trial.

Because of its comparatively large diameter, the moisture content of an "air-seasoned" pole varies considerably. For example, the outer portion may contain only 10 percent of moisture

FIG. A.—Cedar poles piled for storage, Michigan. (Forest Service photo.)

FIG. B.—Poles properly piled for air seasoning, Black Forest, Germany. (Forest Service photo.)

(Facing page 158.)

FIG. C.—An open tank pole treating plant. A poor design, note creosote evaporating from tanks. (Forest Service photo.)

FIG. D.—Creosoted poles for heavy construction, Hayes, England. (Forest Service photo.)

while the interior has 40 percent or over. It is not necessary or practicable to reduce this interior moisture very materially for it does not seriously affect any preservative treatment which might be given.

The effect of this moisture loss on freight shipments is very important, especiallv in long hauls.

TABLE 16.—SHOWING SAVING IN FREIGHT EFFECTED BY AIR-SEASONING POLES

| Species | Size of pole | | No. of poles required for carload of 40,000 lb. | Total decrease in weight due to air seasoning (pounds) | Saving in freight on carload lots | |
|---|---|---|---|---|---|---|
| | Length, feet | Top diameter, in. | | | 25 cent rate, dollars | 15 cent rate, dollars |
| Chestnut............ | 30 | 7 | 43 | 7,700 | 19.25 | 11.55 |
| Southern white cedar. | 30 | 7 | 74 | 16,900 | 42.25 | 25.35 |
| Northern white cedar. | 30 | 7 | 91 | 12,800 | 32.00 | 19.20 |
| Western red cedar.... | 40 | 8 | 59 | 12,900 | 32.25 | 19.35 |
| Western yellow pine... | 40 | 8 | 46 | 38,400 | 96.00 | 57.60 |

The decrease in weight from a green to an air-dry condition varies from about 20 to 50 percent, or 180 to 850 pounds per pole. The decrease in shipping weight and freight charges is, of course, in direct proportion to these percentages.

The shrinkage in the circumference of poles due to their seasoning is insignificant, contrary to general belief. Consequently, if a pole is measured when green, these figures can be considered as practically unaltered by subsequent drying, since the shrinkage will not exceed 1 percent. Exact data on shrinkage taken from measurements on about 2000 poles of chestnut, cedar and pine averaged from 0.3 to 0.5 percent of the green circumference 6 feet from the butt to 0.6 to 0.9 percent at the top. This is equivalent on 30- to 40-ft. poles to about 0.1 or 0.2 inch in the circumference of the butt and from 0.15 to 0.25 inch at the top.

If the poles are steam seasoned, they are handled in much the same manner as cross-ties, viz., placed in the treating cylinder and subjected to live steam at pressures not exceeding 40 pounds for four or more hours, after which a vacuum is applied and the preservative injected.

**Methods of Treatment and Their Selection.**—Because of their large size and the high cost of handling and shipping them and the comparatively small number assembled at one point,

the treatment of poles is quite a different problem from the treatment of ties. Furthermore, poles are not subject to the same kind of deterioration as ties. That portion which projects above ground is much less subject to decay than that in the ground, and in temperate climates like the northern and western United States, where the humidity and temperature are generally low, the tops may last indefinitely. In warm, humid climates, as in the South, a protection to the top is desirable and often—as in the case of pines—necessary. Poles do not fail from mechanical wear, so that this factor need not be considered.

Several methods of protecting the life of poles from decay and insects—the chief destructive agents—are practised. These are (1) setting the poles in crushed stone or concrete, (2) charring the butts, (3) brush treating the butts with a wood preservative, (4) impregnating the butts with a preservative, and (5) impregnating the entire pole with a preservative.

**Setting in Crushed Stone or Concrete.**—If the hole into which the pole is to be placed is dug several inches wider than the pole, crushed or small field stones can be pounded around the pole after it is set. These will permit more or less circulation of air around the butt and keep weeds from growing close to the pole. In this way a partial protection is afforded which will add a year or two to the life secured. Furthermore, the stones will tend to protect the pole from ground fires. Sand placed in such holes affords no protection and may even hasten decay. The author has little evidence that poles set in concrete are materially prolonged in service. Such concrete jackets are liable to become broken and hence admit water. All of these methods are considered make-shifts and should be used only when no better treatment can be had.

**Charring.**—Provided the poles are air seasoned, charring to a depth of 1/4 in. from the butt to about 2 ft. above ground line will more than pay for itself. It is, however, an inefficient method of treatment and adds but little to the life of the pole. If charred green, the poles are very liable to check open and decay hastened rather than retarded. Charring, furthermore, destroys the outer fibers of the wood and weakens the pole where strength is most needed. Charred poles examined by the author were also readily attacked by insects.

**Brush Treatment.**—These should be applied to poles only after they are air seasoned. If applied to green poles, the effec-

tiveness of the treatment will be greatly decreased. The methods of applying brush treatments have already been described (see Chapter V). To secure best results, particularly for poles set in sandy soil, the entire butt and end of the pole should be coated with the preservative and the protection should extend 1 or 2 feet above the ground line. If poles are well treated by this method, their life can be extended from 3 to 6 years. When no better method can be afforded, brush treatments are recommended. The best preservative thus far known is coal-tar creosote, which should be applied hot (about 160° F.) in two coats. For reliable results secured to date the reader is referred to Fig. 118, appendix.

**Open-tank Butt Treatments.**—If the top of the pole is not subject to decay, a butt treatment in an open tank is the best known. (See Plate XV, Fig. C.) (For description see open-tank treatment, Chapter V.) A number of test poles treated in this manner have shown excellent results (see Fig. 31 and Fig. 32, appendix), and because the preservative is confined to the butt of the pole where decay is most active, the method is more economical than if the entire pole is impregnated. Unfortunately, in order to cut down labor and maintenance costs, such treatments are feasibly only where comparatively large numbers of poles are assembled at one point. Furthermore, the treatment may mean a delay in shipment, although it is felt that this objection should be met on the part of pole consumers by anticipating their orders in sufficient time to enable the treatment to be made.

Coal-tar creosote to the amount of 10 pounds per cubic foot, or more if possible, will give best results. It is possible, however, to impregnate the butts with zinc chloride or other antiseptic salts, either alone or in combination with the creosote, in which case a decrease in the cost of the preservative can be made. In any event, the aim should be to treat all of the sapwood to a height of 1 to 2 feet above ground level.

Butt treatments are now given which often amount to little more than dipping treatments, and while they are better than a mere brushing of the pole, they will not prove as effective as though the preservative is driven through the sapwood. In some cases, the surface of the pole has been perforated with small holes in order to facilitate the entrance of the preservative and shorten the time of treatment.

Poles to be butt-treated are hoisted by a derrick into open tanks, where they are stood on end. The preservative is then admitted until the butts are submerged. If creosote or a similar oil is used, it is heated to about 215° F. for two or more hours, after which it is permitted to cool, or cool oil is pumped into the tank and the butts kept submerged until the desired absorption is obtained. In a similar manner the poles can be treated with zinc chloride. By running the hot oil out of the tank and admitting a zinc-chloride solution, a combination treatment can be obtained, or the poles can be lifted out of the hot tank and stood in a second tank containing the solution. Table 17 gives some results secured in butt-treating poles by the open-tank method and shows the amount and depth to which the preservative was absorbed.[1]

TABLE 17.—AVERAGE ABSORPTION AND PENETRATION OF CREOSOTE OBTAINED IN THE BUTT TREATMENT OF POLES BY THE OPEN-TANK METHOD

| Species | Absorption per pole | Penetration | Species | Absorption per pole | Penetration |
|---|---|---|---|---|---|
| | Pounds | Inches | | Pounds | Inches |
| Chestnut | 21.5 | 0.3 | Western yellow pine | 81.4 | 3.1 |
| Northern white cedar | 48.4 | 0.5 | Lodgepole pine | 34.0 | 1.0 |
| Western red cedar | 39.5 | 0.8 | | | |

**Entire Impregnation.**—If the poles decay in the top as well as in the butt, the entire pole should be treated. This is done by placing them on cylinder cars and running them into a treating cylinder. The treatment is very similar to that given ties, no special apparatus being required except that the cars should be of the bolster type in order to take curves. The best process is the full-cell creosote injecting about 10 pounds of oil per cubic foot. This method of treatment is most expensive on account of the large amount of creosote absorbed. It should not be used if open-tank treatments will suffice. A modified treatment has been suggested whereby the poles are run into horizontal cylinders mounted on pivot bearings, after which the cylinder is revolved to a vertical position. In this way it is possible to impregnate the butt under pressure and give the top of the pole a lighter treatment, thus saving materially in total cost. So far as known

[1] Bulletin 84, U. S. Forest Service, by Wm. H. Kempfer.

to the author, this method has not been practised thus far, although it has much to commend it.

**Boucherie Process.**—In this process, which is extensively used in France and which has been tested in our country, the poles are treated green and before the bark is removed. (See Plate XVI, Fig. A.) In fact, the sooner the treatment can be given after the trees are cut the better the results secured. A clamp is placed over the butt of the pole, which is placed in a horizontal position; through this clamp a hole is bored, into which a wooden plug is inserted. The plug is connected to a hose, which in turn is fastened to a larger hose or pipe. A barrel or other vessel filled with copper sulphate, and elevated about 20 ft. above the pole so as to give a static pressure, is connected by means of a hose to this feed pipe. In this way the copper-sulphate solution runs out of the overhead tank and forces its way into the butt of the pole and eventually through its entire length. As soon as the solution appears at the top end, the pole is disconnected from the treating apparatus, after which it is peeled, trimmed, and air seasoned. It is then ready for use.

The Boucherie process is very well adapted to the treatment of poles in small quantities and in rough country where there is a supply of timber suitable for poles and where the cost of transporting treated poles would be prohibitive. Experiments with this process were made by the U. S. Forest Service in California, the time required to impregnate the various poles being given in Table 18.[1] The poles were treated green under a pressure of about 10 pounds. Their length was about 22 ft.

TABLE 18.—TIME REQUIRED TO TREAT GREEN POLES BY THE BOUCHERIE PROCESS

| Species | Average time required to impregnate poles |
|---|---|
| | (Days) |
| Yellow pine | 3.5 |
| White fir | 2.9 |
| Douglas fir | 6.2 |
| Incense cedar | 1.9 |
| Sugar pine | 3.1 |

**Kyan Process.**—This process has been used extensively in Europe for treating poles and has given very good results. The

[1] From report by Geo. M. Hunt and C. S. Smith, of the U. S. Forest Service.

manner in which the process is operated has been described in Chapter V. Next to poles impregnated by the full-cell process, Kyanized poles have given greatest durability. The treatment is comparatively inexpensive when compared with the full-cell creosote and in addition the surface of the poles is clean and free from oily exudations. It is believed the process can be adapted to many conditions in our country and is well worthy of a more extended trial. While no tests which have been made are known by the author, it is probable that a treatment with mercuric chloride can be given poles in much the same manner as they are now treated by the Boucherizing process, although the uniformity of the penetration might not be as good as when the poles are first air seasoned.

**Reenforcing Decayed Poles.**—The expense of replacing decayed poles with new ones is considerable, as all the wires must be restrung, in addition to replacing the pole proper. For this reason, some companies have attempted to reenforce their decayed poles in an effort to prolong their life. Two methods have been rather extensively tried, viz., reenforced stubs and reenforced jackets. The former consists in placing a stub buried in the ground next to the pole and bolting or wiring the pole to it. (See Plate XVI, Fig. B.) These stubs are often creosoten by the brush or full-cell method. They undoubtedly increase the strength of the decayed pole but their reenforcement is only temporary and final removal is generally deferred for but a comparatively short period.

An effective method consists in cutting all decayed wood from the pole for some distance below and above ground. The pole is then brush treated with a preservative like creosote, after which steel reenforcing rods are driven into it and the whole buried in creosote. This method is claimed to give very good results and add materially to the strength and life of the pole. No definite records on the added life thus secured are, however, known to the author, but an estimated life of 8 to 10 years is claimed. The cost of such a treatment is about $3.50 to $5 per pole. (See Plate XVI, Fig. C.)

In some cases, after a pole has decayed, it is cut off at the ground line, the decayed butt removed, and the pole lowered in the same hole. This practice is common and feasible when the length of the pole is sufficient to stand this shortening. It is believed that better results would be secured if the sound por-

FIG. A.—A Boucherie pole treating plant, Fulda, Germany. (Forest Service photo.)

FIG. B.—Partially decayed pole reenforced with a creosoted stub. (Forest Service photo.)

(Facing page 164)

PLATE XVI

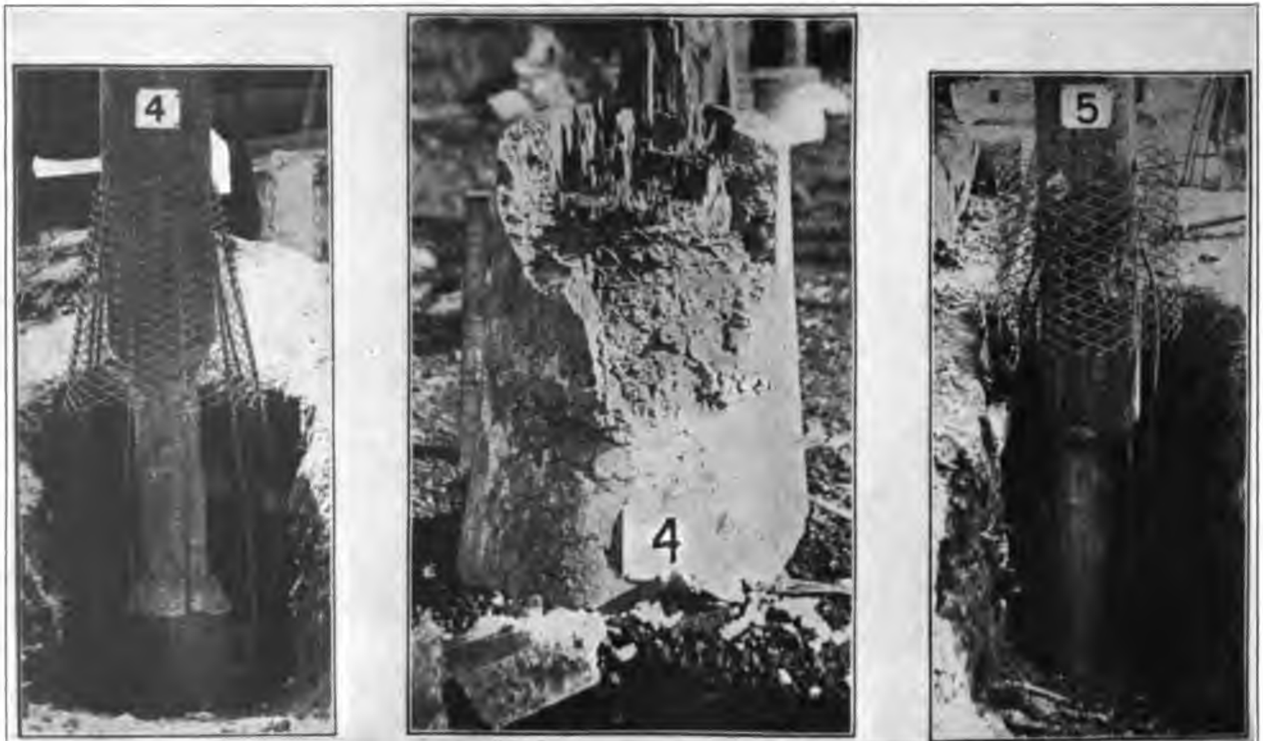


FIG. C.—Method of reenforcing a partially decayed pole with a concrete jacket. (Photo courtesy of the Pittsburg Reenforcing Pole Co.)

tion of the pole was given two coats of hot creosote before it was lowered into the ground. As the ground about the hole is infected with decay-producing fungi, the life of a pole set in such soil will not be as great as the life of a pole set in a freshly dug hole.

**Cost of Treatment.**—The cost of treating poles varies through wide limits. It depends chiefly upon (1) the process used, (2) the size of the pole, (3) the cost of the preservative, (4) the cost of labor, and (5) the number of poles treated per day. In order to have some general data, however, Table 19 has been compiled, but in using it the reader is cautioned against drawing too sharp conclusions. Creosote is assumed to cost 1 cent per pound, labor $2 per day, the size of pole to be 30 feet, and the treatments given as already described.

TABLE 19.—ESTIMATED COST OF TREATING POLES

| Kind of treatment | Amt. of preservative used per pole (pounds) | Cost per pole |
|---|---|---|
| Field or crushed stone around pole | .............. | $0.00–$0.20 |
| Charring butt | .............. | 0.05– 0.15 |
| Brush treatment (2 coats creosote) | 8[a] | 0.15– 0.30 |
| Open-tank butt treatment creosote | 50[b] | 1.00– 1.50 |
| Entire pole treated—full-cell creosote | 144[c] | 1.70– 2.25 |

[a] = about 24 square feet surface.
[b] = about 6 cubic feet treated.
[c] = about 18 cubic feet treated.

A more detailed estimate of the cost of butt-treating poles, based on an open-tank plant having a daily capacity of 120 poles per day or 30,000 per year (250 working days), is as follows:[1]

LABOR PER DAY

| | | |
|---|---|---|
| 1 yard foreman | $4.00 | |
| 1 plant engineer | 4.00 | |
| 1 stationary engineer | 4.00 | |
| 2 firemen, at $2.50 | 5.00 | |
| 5 laborers, at $2 | 10.00 | |
| Total | $27.00 | |
| Labor charge per pole | | $0.225 |

FUEL PER DAY

| | | |
|---|---|---|
| 2 tons coal, at $4 | $8.00 | |
| Fuel charge per pole | | 0.067 |

[1]Bulletin 84, U. S. Forest Service.

MAINTENANCE PER YEAR

| | | |
|---|---|---|
| Depreciation and repairs | $500.00 | |
| Interest on investment in plant and preservatives | 400.00 | |
| Total | $900.00 | |
| Maintenance charge for pole | | $0.030 |
| Seasoning charge per pole (interest on investment) | | 0.100 |
| Total treating charge, exclusive of preservative | | $0.422 |

The cost of treatment, exclusive of preservative, based on a liberal estimate for all charges, is thus seen to be $0.422 per pole. To this should be added the cost of the preservative, taxes on property, and, if the treating plant is not located at a central seasoning or distributing yard, extra shipping charges.

**Economy of Treatment.**—Treated poles have not been in use in this country for a sufficient period to furnish actual data on the length of time their life has been prolonged. In Germany, where fairly accurate information is at hand, the following results have been secured based on about 50 years experience:

| | |
|---|---|
| Untreated poles | 7.7 years average life |
| Poles treated with copper sulphate | 11.7 years average life |
| Poles treated with zinc chloride | 11.9 years average life |
| Poles treated with mercuric chloride | 13.7 years average life |
| Poles treated with creosote | 20.6 years average life |

The amount of creosote injected in each case, and the exact conditions under which the poles were set, are not known. We have records in this country, however, of longleaf pine poles treated by the full-cell creosote process and set in Virginia which are perfectly sound after 18 years' service. Accurate records on the durability of poles in the United States, so far as these are at present obtainable, are given in Fig. 31 and Fig 32, appendix. Using them and the cost of treatments given above, the economy of treatment can be approximated as in Table 20.

It will be noted from the estimates given in the table that poles butt-treated with creosote by the open-tank method are the cheapest to maintain. In this connection, however, several factors should be kept clearly in mind. It has been assumed in the table that the tops of the poles do not decay. While this condition is true for a large part of our country, it must not be universally applied. If the top is subject to decay, the full-cell creosote process will undoubtedly be found to give lowest main-

tenance charges, although its initial cost of installation will remain highest. Another very important point is the kind of wood used in the pole. Northern white cedar has been selected in the table because of its uniform excellence and very extended use. If other varieties are employed the annual charges shown in the table will, of course, be materially changed. For example, a loblolly pine pole will last untreated about 4 years, whereas the northern white cedar is estimated at 14 years. When given a butt or full-cell treatment with creosote, the difference in the annual charges between treated and untreated loblolly pine poles will be much greater than the differences between treated and untreated cedar poles, because of the natural durability of the latter. Consequently, poles possessing less natural durability will, when treated, show greater economy in treatment than poles possessing great natural durability. Furthermore, the lower price at which such poles can generally be secured will frequently make their use, when properly treated, cheaper than the more naturally durable poles. The wide range through which these conditions vary frustrates any attempt to arrange them in a table that would be of practical value, hence no attempt to do so has been made.

TABLE 20.—ESTIMATED ANNUAL CHARGES OF CEDAR POLES TREATED BY VARIOUS METHODS

| Method of Treatment | Cost of treatment | Cost of pole set in line | Estimated life | Annual charge |
|---|---|---|---|---|
| | $ | $ | Years | $ |
| Untreated | ........ | 7.00 | 14 | 0.71 |
| Charred at butt | 0.15 | 7.15 | 15 | 0.69 |
| Butt brush-treated | 0.25 | 7.25 | 18 | 0.62 |
| Boucherie | 0.70 | 7.70 | 20 | 0.62 |
| Butt treated zinc chloride (open tank) | 0.60 | 7.60 | 22 | 0.58 |
| Butt treated mercuric chloride (open tank) | 0.90 | 7.90 | 24 | 0.59 |
| Butt treated creosote (open tank) | 1.25 | 8.35[1] | 30 | 0.54 |
| Full-cell creosote (pressure) | 2.29 | 9.50[1] | 30 | 0.62 |

Pole— northern white cedar.
Life— untreated = 14 years.
Cost of pole = $4.
Cost of placement = $3.
Size of pole = 30 feet.
Interest 5 percent compounded annually.

[1] Extra charge for increased weight due to treatment.

## CROSS ARMS

**Selection of Species.**—Two kinds of wood, Douglas fir and pine (mostly longleaf), furnish about 90 percent of the 3,500,000 cross arms used annually in the United States. Other varieties such as oak, cypress, spruce, juniper, cedar, chestnut, and locust are also used, but in scattering quantities. Due to the manner in which they are placed, decay in cross arms is not nearly as serious as decay in poles. The problem of selecting material for cross arms is therefore largely confined to those species which occur in sufficient quantities in one locality and thus warrant the installation of the special machinery necessary to manufacture cross arms at low cost. Douglas fir and longleaf pine are the woods now most largely manufactured into lumber and occur in enormous stands over a wide area. The intrinsic properties desired in a cross arm are strength, freedom from warping and checking, a comparatively light weight, and resistance to decay. Even when the arms are to be treated, their ability to absorb the preservative is not of prime importance, as only small quantities of an efficient preservative are necessary in order to protect them from decay. For greatest strength at least weight, redwood is one of the best cross-arm materials used and it is surprising that more redwood arms are not in service. A distinction is made between arms cut from Douglas fir, the trade recognizing two distinct types known as "yellow" and "red" fir. The former is claimed to be the better arm and far more durable than the latter, cases being on record where such arms untreated were in service over 40 years without any signs of decay. It is probable, however, that this long service was due to the comparatively dry climate (Utah) in which these arms were used.

**The Manufacture of Cross Arms.**—It is quite essential that the wood from which cross arms are made be of straight grain free from defects such as knots, spiral grain, checks, etc., which tend to decrease their strength. This is especially true for that portion of the arm at and near the middle, as failure is most likely to occur at this portion.

It is also important to have the arm brought to exact dimensions and all holes bored before any preservative treatment is given.

**Methods of Seasoning.**—On account of their comparatively small size and the ease with which they can be handled, cross

arms are generally air seasoned before they are shipped or treated. The usual precautions for the condition of the seasoning yard, as described in Chapter VIII, hold as well for cross arms. Many forms of piles have been tried but those which give best satisfaction are open piles without roofs, in which the end arms in each tier are placed with their depth vertical while the arms in between are placed with their depth horizontal. (See Plate XVII, Fig. A.) This allows a free circulation of air and induces rapid drying.

From a large number of measurements, the shrinkage in coniferous cross arms from a green to air-dry condition is of little or no practical significance. The same holds for any changes in the shape of the holes bored into the arms. In hardwood cross arms these changes are much greater.

Cross arms season rapidly and reach an air-dry condition in about 1 month. In summer this rate may even be exceeded, while in winter or rainy weather longer periods are of course necessary. Some experiments were made by the U. S. Forest Service in air-seasoning loblolly pine arms, which, according to the amount of sapwood they contained, were divided in three charges, heartwood, sapwood, and intermediate. The manner in which these arms seasoned is shown in Table 21.[1]

TABLE 21.—COMPARATIVE RATES OF SEASONING OF LOBLOLLY PINE HEARTWOOD, SAPWOOD, AND INTERMEDIATE CROSS ARMS

| Days seasoned | Heartwood | | | Sapwood | | | Intermediate | | |
|---|---|---|---|---|---|---|---|---|---|
| | Weight per arm | Weight per cubic foot | Moisture content | Weight per arm | Weight per cubic foot | Moisture content | Weight per arm | Weight per cubic foot | Moisture content |
| | Pounds | Pounds | Percent | Pounds | Pounds | Percent | Pounds | Pounds | Percent |
| 0 | 38.8 | 42.6 | 51.5 | 52.7 | 57.9 | 105.8 | 45.8 | 50.3 | 79.0 |
| 30 | 34.2 | 37.6 | 33.4 | 34.5 | 37.9 | 23.8 | 34.8 | 37.7 | 34.0 |
| 60 | 33.9 | 37.3 | 32.5 | 32.6 | 35.8 | 27.2 | 33.3 | 36.6 | 30.0 |
| 90 | 34.3 | 37.3 | 33.8 | 32.6 | 35.8 | 27.3 | 33.4 | 36.7 | 30.3 |
| 120 | 34.2 | 37.6 | 33.7 | 32.5 | 35.7 | 26.9 | 33.4 | 36.7 | 30.3 |
| 150 | 33.9 | 37.3 | 32.3 | 32.1 | 35.3 | 24.5 | 33.0 | 36.3 | 29.0 |
| 180 | 33.6 | 36.9 | 31.2 | 31.6 | 34.7 | 23.6 | 32.5 | 35.7 | 26.9 |

**Methods of Treatment and Their Selection.**—As above stated, cross arms are not subject to severe attack by fungi, since they are surrounded on all sides by air and are raised a considerable distance above ground. Decay is most likely to occur at the bolt and pin holes. It is quite essential, therefore, to have these properly protected. If the arm is of a naturally durable wood such as white or red cedar, heart cypress, etc., no preservative treatment

[1] Circular 151, U. S. Forest Service.

is necessary, as the arm will unquestionably last much longer than the pole. If, however, the wood is not so durable, such as pine, fir, spruce, etc., a preservative treatment is desirable.

If the preservative selected is a salt, such as zinc or mercuric chloride, objections can be raised in that it will tend to wash from the wood, it will attack the iron spikes or bolts, and it will tend to keep the arms more or less moist thus lowering the strength of the arms and decreasing their resistance to the leakage of electric current.

On the other hand, if creosote is used, it will tend to volatilize quickly from the arms, or if large quantities are injected danger from drip may be encountered. Cases are on record where companies have been forced to replace their arms because of the damage done by such dripping. Arms heavily creosoted are, moreover, increased perceptibly in weight.

Taking all these factors into consideration, it is believed that arms treated with about 5 to 6 pounds of creosote per cubic foot by an empty-cell process so that no drip will occur will give best results. In doing this, however, it is important to use a high-grade preservative, so that loss from volatilization can be kept to a minimum.

Dipping the arms in a tank of hot preservative such as coal-tar creosote or carbolineum for several minutes should also give good results. The oil will run into all checks and holes and, as wood is most easily treated in the direction of the grain (longitudinally), a good penetration will be secured at those points which require greatest protection.

Kyanized arms are reported to have given excellent service. The process produces clean arms and adds practically no dead weight.

**Cost of Treatment.**—The cost of treating cross arms is very variable. When large quantities are handled and apparatus is at hand for doing the work mechanically, the cost is kept at a minimum. It has been assumed in the estimates given in Table 22 that these mechanical features have been provided.

TABLE 22.—APPROXIMATE COST OF TREATING CROSS ARMS

| Process used | Total cost per arm (10-pin) (cents) |
|---|---|
| Full-cell creosote | 10–20 |
| Empty-cell creosote | 7–10 |
| Dipping creosote | 4– 8 |
| Dipping carbolineum | 10–30 |

FIG. A.—Cross arms properly piled for air seasoning. (Forest Service photo.)

FIG. B.—Creosoted cross arms just leaving the treating cylinder, Norfolk Creosoting Co. (Forest Service photo.)

(Facing page 170.)

PLATE XVII

FIG. C.—Fence posts properly piled for air seasoning. (Forest Service photo.)

FIG. D.—Untreated lodgepole pine post set four years. Note decay at the ground. (Forest Service photo.)

**Economy of Treatment.**—Only estimates based upon the opinions of operators and our knowledge of the decay of wood can be given in arriving at the probable economy resulting from the preservative treatment of arms. No authenticated records are known to the author of the service secured from treated arms in actual use. It is only reasonable to expect that climatic conditions will affect very materially the life of cross arms. For example, arms in the South where the air is often warm and moist will tend to decay much more rapidly than arms in dry or cold climates. In fact, it is doubtful whether the treatment of arms, other than a mere soaking in the preservative of the bolt and pin holes and the center portion in contact with the pole, under these latter conditions is at all feasible or necessary. As has been stated, cases are on record of yellow fir arms which in a comparatively dry climate like Utah and Nevada lasted untreated for over 40 years without any signs of decay. Of course, such conditions cannot be expected for the greater part of our country, so that a treatment of some sort is generally advisable.

The estimates given in Table 23 are very rough as no data could be found giving the lives of cross arms treated in the manner suggested.

TABLE 23.—ESTIMATED ANNUAL SAVING DUE TO TREATMENT OF CROSS ARMS (INTEREST COMPOUNDED AT 5 PERCENT)

| Item | Fir | Pine |
|---|---|---|
| Life untreated (years) | 15.0 | 10.0 |
| Life treated by empty-cell process (years) | 25.0 | 30.0 |
| Life treated by dipping process in creosote (years) | 20.0 | 18.0 |
| Life treated by dipping process in carbolineum (years) | 21.0 | 19.0 |
| Cost untreated in place (dollars) | 1.50 | 1.50 |
| Cost treated by empty-cell process in (place) | 1.58 | 1.58 |
| Cost treated by dipping process using creosote | 1.56 | 1.56 |
| Cost treated by dipping process using carbolineum | 1.60 | 1.60 |
| Annual charges untreated | 0.150 | 0.190 |
| Annual charges treated by empty-cell process | 0.110 | 0.100 |
| Annual charges treated by dipping process (creosote) | 0.125 | 0.130 |
| Annual charges treated by dipping process (carbolineum) | 0.125 | 0.130 |

# CHAPTER X

## PROLONGING THE LIFE OF FENCE POSTS FROM DECAY

**Selection of Species.**—Where trees abound, fence posts are generally made from timber easiest to cut. For this reason practically all kinds of wood large enough to make a post are used and a list of them would comprise nearly all species which grow in our country. Where post timber is scarce, greater care is taken in selecting the kinds of wood cut into posts, and in any event the durable species are almost invariably the best ones to use. Aside from the question of cost, which is always of first importance, the qualities demanded of a good post wood are durability, form, and ability to hold staples or nails. If the posts are to be given a preservative treatment, their ability to take treatment must also be considered.

The durability of posts is very variable even when cut from the same kind of wood, so that any estimates on durability must be judged with considerable latitude. Posts set in wet ground are more durable than posts set in soil alternating wet and dry. Posts cut from slow-grown trees are generally more durable than posts cut from rapid-grown trees. To these variations must be added the variations due to climatic conditions.

The best formed posts come usually from the coniferous trees like cedar, pine, fir, etc., and fences set with them have the neatest appearance. Crooked posts are more liable to pull the staples, as the wires fastened to them are not in alignment.

In general, the staple or nail-holding power of a post varies with its dry weight. That is, posts cut from heavy woods like locust, oak, etc., will hold staples better than posts cut from light woods like pine and cedar.

If the posts are to be set untreated, the more heartwood they contain the better. Consequently, split posts are generally more durable than round posts. If, however, a preservative treatment is to be given, round posts are preferable, as the sap-

wood can be more easily impregnated than the heartwood and a continuous layer of preserved wood will then extend continually around the post.

**Method and Time of Cutting Posts.**—As just mentioned. split posts containing mostly heartwood are preferable to round posts if they are to be set untreated. So far as possible, the ends of the posts should be cut with an axe or fine saw, especially if the posts are of soft wood. A smooth cut enables rain water to run off more freely and is less liable to cause top decay. A slight bevel to the top of the post is also desirable and should be given. If, however, the posts are subject to "frost heave," that is, thrown out of alignment by frost, the bottoms should be pointed so they can be reset upright in the spring and driven into the ground with a mallet. With such posts, too great a bevel to the top should be avoided.

It is generally conceded that the best time of the year to cut posts is in winter or late fall, as they are at such seasons less subject to immediate attack by fungi. Furthermore, sprouts from winter-cut stumps are far more vigorous than sprouts from stumps cut in spring or summer. In fact, the sprouting capacity of a stump may sometimes be killed by summer cutting.

In all cases, whether treated or untreated, posts should be peeled, as the bark offers practically no protection and generally does a positive harm. All bark should be thoroughly removed from that portion of the post to be treated with the preservative so that the preservative can have an opportunity to penetrate uniformly into the wood.

**Method of Seasoning.**—Whether or not it pays to season posts which are to be set untreated is still an open question. It appears, however, that the seasoning adds but little to the life of the posts and if it entails much delay or expense is not warranted.

Of course, where a preservative treatment is to be given, seasoning is as a rule highly advisable, as better penetrations are secured and the protective coating is less subject to injury due to subsequent checking. A simple and effective means of seasoning posts is to pile them in horizontal layers, allowing sufficient space between each post so that air can circulate about them. (See Plate XVII, Fig. C.) If the posts are liable to check seriously, as in the case of the gums and oaks, it is best to pile them closer together and in a shady place. One or two months are

generally required to produce an air-dry condition but in warm weather two weeks may be sufficient.

**Methods of Treatment and Their Selection.**—Farmers are the largest consumers of posts, and most of them make their own posts. The chief requirement for a preservative treatment is, therefore, that it shall be one which the farmer can give himself. In some localities where the posts are bought, a rather elaborate treatment can be given and the posts sold in a treated condition. For the most part, however, the most practical methods are those which are simple of execution. The ones most commonly used are described below.

**Setting Posts in Stones.**—If stones are abundant, this method is better than setting the posts directly into the soil. If the stones must be hauled long distances, the method will not pay, as it does not materially increase the life of the posts. Its chief advantage lies in that it keeps weeds and vegetation away from the base of the post, thus prolonging its life and protecting the post from ground fires.

**Setting Posts Upside Down.**—This is done on the theory that rain-water will run out of the post more readily in this position than when set large end down. There is no evidence whatever to substantiate this and were it not for the widespread belief in this method it would not even be commented upon here. An obvious objection to this method is that it places the small end of the post in the ground and hence gives a weaker post than if set the other way, since greater strength and resistance are required in the butt than in the top.

**Charring the Butt.**—Charring at best is a poor method of treatment, since its effect is but slight. If the posts are charred they should first be air seasoned thoroughly and charred from the butt to about 6 inches above the ground line. The charr should not extend more than 1/4 inch into the post. While this treatment will tend to increase the durability of the post, it also weakens it at the very point where it needs greatest strength. However, if the charring can be done at slight expense, it will more than pay for itself through added durability.

**Dipping in Crude Oil and Charring.**—If the butt ends of the posts are dipped for a few minutes in crude oil and then charred better results than simple charring are obtained. (See Plate XVIII, Fig. A.) This method is, however, also subject to criticism in that it weakens the posts at the butt. It seems that

burning the posts after their oil treatment tends to drive some of the hot oil into the wood. Some experiments made along this line by the Wyoming Experiment Station showed pitch-pine posts to be sound after 16 years of service. It should be stated, however, that these posts set untreated under similar conditions would last at least 12 years, so that the efficacy of the treatment is not pronounced.

**Diagonal Holes Filled with Preservative.**—This method of treatment consists in boring 2 or 3 holes about 1/2 inch in diameter and 3 inches deep diagonally downward into the post near the ground line, and pouring a preservative such as a solution of copper sulphate, mercuric chloride, kerosene, etc., into the hole, after which it is plugged. When the preservative escapes from the cavity, the plug is removed and more inserted. This treatment is not recommended, first because it weakens the post, second because the preservative does not diffuse evenly through the post as claimed, and third because the results secured are not sufficient to pay for the trouble and expense of the treatment.

**Brush Treatments.**—If posts are first air seasoned and then given two coats of a good preservative like coal-tar creosote or carbolineum in the manner described in Chapter V, their natural life can be increased from 3 to 6 years. The entire butt of the post should be treated to a distance about 1 foot above the ground line. The preservative had best be applied hot and worked into the cracks as completely as possible. Brush treatments when properly applied will more than pay for themselves but are not as efficient as can be given. In the case of posts that decay at the top, such as maple, gum, etc., it is well also to brush-treat the top.

**Dipping Treatments.**—These are more effective than brush treatments, as the preservative is sure to run into all checks. As posts can be easily handled, this method is recommended, particularly where only a few posts are to be treated. Creosote or a similar preservative is the best obtainable for dipping treatments. All that is necessary is to have the preservative hot (about 150°–180° F.) and dip the butt ends of the post in a tank or barrel containing the oil for about 1/4 minute, after which they can be removed. The post should be submerged to a depth of about 1 foot above the ground line. One dipping will give good results. Better absorptions and penetrations will be secured, however, if the post is dipped twice, a sufficient time elapsing

between treatments to allow the first to dry. Tar is not recommended for either brush or dipping treatments.

**Impregnation Treatments.**—Treatments of this kind are the best known, although the most troublesome and expensive to make. If the preservative selected is a salt like zinc or mercuric chloride or copper sulphate, all that is necessary is to stand the air-seasoned posts in a tank or vessel containing a solution of the preservative. For zinc chloride a 6 percent solution is recommended, while for copper sulphate 1.5 percent and for mercuric chloride 0.9 percent is sufficient. If the latter salt is used great care should be taken in handling it and keeping it away from animals because of its very poisonous nature. With copper and mercury solutions, wooden or stone vessels or tanks should be used, as they will attack iron. The posts should remain standing in the preservative for about 1 week.

Better results can be secured with coal-tar creosote, but to get most effective treatments the oil should be heated as described in Chapter V. If but one tank is used, the oil and posts can be heated and then allowed to cool in it. This cuts down the number of posts that can be treated per day and is called a "single-tank treatment." If two tanks are used, one for hot oil and one for cool oil, quicker results are secured. Such treatments are known as "double-tank treatments." The U. S. Forest Service has made a large number of tests in treating posts by these methods and has obtained some very satisfactory results. These are shown in Table 24.

The treating tanks necessary to treat posts in this manner and the method of operating them are described in Chapter V (open-tank process).

While no tests that have been made are known to the author, it is believed that if the posts are boiled in crude oil or any cheap oil for 2 or 3 hours and then quickly plunged into a tank containing a solution of zinc chloride, copper sulphate, or mercuric chloride at atmospheric temperature, as described above, and left standing in this solution for 3 or 4 hours, very good results will be secured and at a lower cost than if only coal-tar creosote were used. It is quite likely that green posts can be treated in this manner and good penetrations obtained, but in such cases the length of the boiling period will probably have to be increased somewhat. In no case should the posts be heated above 275° F.

TABLE 24.—BEST RESULTS SECURED IN THE TREATMENT OF VARIOUS WOODS[1]

(All posts were round, peeled, and seasoned)

| Species | Absorption creosote per 5-inch post | Penetration | | Single-tank treatment | | | Double-tank treatment | |
|---|---|---|---|---|---|---|---|---|
| | | 2 feet from butt | 2 feet from top | Butt: Hot oil | Butt: Cooling oil | Top | Hot oil | Cold oil |
| | Gal. | In. | In. | Hr. | Hr. | | Hr. | Hr. |
| Ash, white | 0.4 | 0.4 | ...... | 5 | 12 | Dipped[a] | ...... | ...... |
| Basswood | 0.6 | 0.1 | 0.05 | ...... | ...... | .......... | 1 | ½ |
| Beech | 0.6 | 1.0 | 0.4 | ...... | ...... | .......... | 1 | ¾ |
| Birch, river | 0.6 | 0.7 | 0.3 | ...... | ...... | .......... | 3 | 1 |
| Butternut | 0.4 | 0.5[b] | ...... | 6 | 12 | .......... | ...... | ...... |
| Cottonwood | 0.4 | 0.6 | ...... | 1 | 12 | Dipped[a] | ...... | ...... |
| | 0.6 | 0.3 | 0.1 | | | | 1½ | 1 |
| Elm, slippery | 0.6 | 0.3[b] | 0.1 | ...... | ...... | .......... | 1½ | 1½ |
| Elm, white | 0.4 | 0.4[b] | ...... | 6 | 12 | .......... | ...... | ...... |
| Gum, black | 0.6 | 0.6 | 0.3 | ...... | ...... | .......... | 1 | 1 |
| Gum, cotton (tupelo) | 0.6 | 0.6 | 0.3 | ...... | ...... | .......... | 1 | 1 |
| Gum, sweet (red) | 0.6 | 1.0 | 0.3 | ...... | ...... | .......... | 1 | ¾ |
| Hickory, bitternut | 0.4 | 0.5 | ...... | 6 | 12 | Dipped[a] | ...... | ...... |
| Magnolia, sweet (bay) | 0.6 | 0.4 | 0.2 | ...... | ...... | .......... | 1 | ½ |
| Maple, red | 0.6 | 1.0 | 0.3 | ...... | ...... | .......... | 4 | 2 |
| Maple, sugar | 0.6 | 0.2 | 0.1 | ...... | ...... | .......... | 3 | 2 |
| Oak, pin | 0.5 | 1.0[b] | 0.5 | ...... | ...... | .......... | 1 | ¾ |
| Oak, red | 0.4 | 0.5 | 0.3 | ...... | ...... | .......... | 1 | ¾ |
| Pine, loblolly | 0.5 | 1.5 | 1.0 | ...... | ...... | .......... | 1½ | 1 |
| Pine, lodgepole | 0.6 | 1.2 | 0.6 | ...... | ...... | .......... | 1½ | 1 |
| Pine, pitch | 0.5 | 1.0 | 0.3 | ...... | ...... | .......... | 3 | 1 |
| Pine, scrub | 0.5 | 1.0 | 0.4 | ...... | ...... | .......... | 3 | 2 |
| Pine, shortleaf | 0.5 | 1.0 | 0.3 | ...... | ...... | .......... | 3 | 1 |
| Poplar, white | 0.5 | 0.5 | 0.2 | ...... | ...... | .......... | 6 | 12 |
| Sycamore | 0.6 | 1.0 | 0.2 | ...... | ...... | .......... | 1 | ½ |
| Tulip-tree | 0.6 | 0.4 | 0.1 | ...... | ...... | .......... | 2 | ½ |
| Willow, white[c] | 0.6 | 0.6 | 0.2 | ...... | ...... | .......... | 4 | 1 |

[a] Dipped for 5 minutes or more.
[b] Width of sapwood. Penetration limited by impenetrable heart.
[c] Requires especially thorough seasoning.

**Pitch Streaks.**—It is well known that pine posts which contain large amounts of resin are more durable than pine posts which are not resinous. This fact is taken advantage of in certain portions of the South by peeling all of the bark off a small tree to a height of 7 or 8 feet except for a strip about 2 inches wide, which is sufficient to keep the tree alive for several years. The tree thus injured covers its wound with resin, which frequently penetrates into the wood for a half inch or more and thus forms pitchy wood. In two or more years the tree is felled and the post cut from it. This method is not recommended, as it is very destructive to timber and wasteful, and the posts are

[1]Farmers' Bulletin 387, U. S. Department of Agriculture.

very liable to catch on fire, if ground fires are common, because of the pitchiness of the wood.

**Cost of Treatment.**—Costs of treatment will be estimated only for brush, dipping, and impregnation treatments, as the other treatments described cost practically nothing except for labor, which is generally supplied by the farmer himself at odd times. If labor is included, the cost of the treatments will, of course, depend upon the number of posts which can be treated per day and the value the farmer puts upon his labor. In the following calculations it is assumed that the apparatus used is such as is described in Chapter V and that the price paid for the chemicals is average for small quantities, viz., creosote 2 cents per pound, zinc chloride 5 cents per pound, copper sulphate 6 cents per pound, and mercuric chloride 70 cents per pound; these being used in the manner specified above. The total cost of treatments per post (6-inch top 7 feet long) will then be about as estimated in Table 25.

TABLE 25.—ESTIMATED COST OF TREATING FENCE POSTS (BUTT ONLY)

| Method of treatment | Total cost per post (cents) |
|---|---|
| Brush-treated coal-tar creosote | 4–6 |
| Dipped coal-tar creosote | 5–7 |
| Impregnated with zinc chloride, copper sulphate or mercuric chloride | 3–7 |
| Impregnated with coal-tar creosote | 12–20 |

If the entire post is treated the above costs will be about doubled.

**Economy of Treatment.**—As the preservative treatment of fence posts cut from durable wood is unnecessary, it will be assumed that only posts having a comparatively short natural life will be given a treatment. In order to approximate the value of the treatments, therefore, we will take as an example posts cut from such woods as red oak, maple, pine, etc., which decay in about 5 years and which are worth about 5 cents each. The cost of setting the posts will be estimated at 12 cents each. With these assumptions and figuring interest compounded at 6 percent, the annual cost of posts treated by the various methods will be as shown in Table 26.

It will be noted that, if the values given in the table are approximately correct, the economy resulting from the treatment of posts is not great. The selection of woods to be cut into posts is perhaps of as great or even greater importance. For this

TABLE 26.—ESTIMATED ANNUAL CHARGES OF TREATED POSTS (BUTT TREATED ONLY)

| Method of treatment | Life of post (years) | Cost of post set in position (cents) | Annual charges (cents) |
|---|---|---|---|
| Untreated | 5 | 17 | 4.0 |
| Brush treated coal-tar creosote | 9 | 22 | 3.2 |
| Dipped coal-tar creosote | 11 | 23 | 2.9 |
| Impregnated with zinc chloride, copper sulphate, or mercuric chloride | 12 | 22 | 2.6 |
| Impregnated with coal-tar creosote | 21 | 33 | 2.8 |

reason, Table 27 is given to show what can be expected from posts cut from a variety of woods. Fortunately, some reliable data from actual experience is available on the life of untreated posts, this data being compiled from painstaking inquiries and researches by Mr. J. J. Crumby of the Ohio Agricultural Experiment Station and published by him as Bulletin No. 219 of that station. He examined 292 fences containing 30,160 posts in Ohio, Indiana, Illinois, Kansas, and Texas. The results are shown in Table 27.

TABLE 27.—LIFE OF FENCE POSTS SET UNPROTECTED

| Kind of wood | Average age of fences (years) | Percent of sound posts at this age |
|---|---|---|
| Osage orange | 33.2 | 99 |
| Locust (black) | 25.4 | 82.3 |
| Red cedar | 33.2 | 65.3 |
| Mulberry | 23.8 | 74.1 |
| White cedar | 18.4 | 68 |
| Catalpa | 17.5 | 61.8 |
| Chestnut | 12.3 | 71.8 |
| Oak (mostly white) | 11.8 | 65.2 |
| Black ash | 6.5 | 64.2 |

It can be seen at a glance that posts cut from such durable woods as osage orange, black locust, red cedar, etc., will far outlast nondurable posts treated by the best methods known and will be far cheaper to use even if they cost considerably more.

The following interesting facts on the life of untreated fence posts are brought out by Mr. Crumley's investigation:

1. "A large post usually lasts longer than a small one of the same wood.

2. There is no difference which end is put in the ground, except that the sounder or larger end should have the preference.

3. In stiff clay soil, the posts rot principally just beneath the top of the ground, and in a porous, sandy, or gravelly soil they usually rot from the top of the soil all the way down.

4. In soil that is full of water all the time, posts will last longer.

5. Timber that grows rapidly and in the open is not as good as the same variety that grows in the woods.

6. There is some evidence that it is not a good time to cut posts just as the tree begins to grow in early spring.

7. The wood at the center of the tree is not as good as that just inside the sapwood. This characteristic is very common with nearly all the varieties of timber examined, especially so with the locust, white cedar, hardy catalpa, and the oaks."

## CHAPTER XI

## PROLONGING THE LIFE OF PILING AND BOATS FROM DECAY AND MARINE BORERS

To satisfactorily treat piling and timber placed in salt water where marine borers abound is exceedingly difficult of accomplishment and the problem is quite different from that of protecting timber from decay. As has been pointed out in Chapter II, it matters little what the wood is, for the borers will rapidly perforate it. The hardest woods like oak and eucalyptus are attacked by them. The most resistant wood known against these attacks is the greenheart, but even this will eventually succumb.

Of course piling driven in fresh water or in the ground is not subject to the attack of marine borers. If such piling is kept continuously submerged or buried, no preservative treatment is necessary, as it will last indefinitely. If, however, parts of it project into the air, decay will take place and some preservative treatment is advisable. The methods described under the treatment for poles may be considered in this connection, except of course if the piling is in water or wet soil soluble salts should not be used.

**Selection of Species.**—A good pile timber should be straight, strong, susceptible to treatment, and of moderate cost. Any wood which has these properties can be used to advantage. These requirements are admirably filled by our common southern pines, the loblolly, shortleaf, longleaf, and Cuban. On the Pacific Coast, western yellow pine and Douglas fir are available, although the latter is objectionable on account of its resistance to treatment by present known processes. Strange to say, two woods which differ greatly in their mechanical properties are used untreated for piling with apparent good results. These are the palmetto, which is comparatively weak and "spongy," and greenheart, which is exceedingly strong and dense. The resistance of the palmetto is supposed to be due to its porous nature and the natural adversion of the teredo to crossing vacant spaces. The greenheart apparently has some peculiarity not at present understood which is unattractive to the marine borers.

If the piling is to be used in waters where attack by marine borers is known to be very rapid, only those woods which have a wide sapwood (about 2 inches in width) should be used, as more preservative can be forced into them and better results thus secured. Where attack is less severe, it seems that piling with sapwood about 1 inch wide is preferable, as this tends to concentrate the oil in the outer portion to a greater extent than when the sapwood is wide. In either case it appears that a concentration (heavy injection) of oil is better than diffusing the same amount of oil more deeply through the wood—a condition quite the reverse of the protection against fungi.

**The Manufacture of Piling.**—In making piling which is to be treated there are two essentials which should be strictly adhered to. First, is a complete removal of all bark from that portion of the pile which will project above the mud line. Bark is very resistant to penetration and if thin strips of it are left adhering to the wood the penetration under such strips may be very slight or none at all; consequently, no matter how well the rest of the pile may be treated, attack will begin at these points and extend rapidly to the interior. Many failures have occurred because this simple rule was violated. (See Plate XVIII, Fig. B.)

The second precaution is to keep the sapwood continuous and not cut into it so as to expose the heartwood at any point which can be reached by the marine borers. Heartwood does not take treatment as well as sapwood, and is always more subject to attack no matter how well the treatment is given. As that portion of the pile which is driven below the mud line is not subject to attack either by decay or marine borers, and hence will last indefinitely, it is believed that much economy in the treatment of piling could be effected by leaving the inner bark adhering to this portion of the pile. In this way, much less oil would be consumed without in any way affecting the life of the pile.

**Methods of Seasoning.**—If the piling can be air seasoned without decay, the method followed is the same as that given for air-seasoning poles. Unfortunately, it often happens that this can not be done, particularly in the South where the air is warm and damp and decay is liable to occur before the pile becomes dry. Some plants store their piling in water prior to treatment or leave them on the ground. Both these methods may become objectionable in that they may cause marked differences in the

FIG. A.—Fence posts dipped in crude oil and then charred. Note good condition after 12 years' service. (Photo courtesy of the Wyoming Exp. Station.)

FIG. B.—Sections of creosoted piling. Note erratic penetrations of creosote. (Forest Service photo.)

(Facing page 182.)

FIG. C.—Pile sheathed with zinc entirely destroyed by marine borers, Pensacola, Fla. (Forest Service photo.)

FIG. D.—Piling protected with cement casings from attack by marine borers, Pensacola, Fla. (Forest Service photo.)

water content of the pile, which in turn is liable to result in unequal penetrations.

When air seasoning is impossible, live steam or oil seasoning can be used. The methods of doing this have been given in Chapter IV. Care should be taken not to use temperatures above 275° F., as injury to the timber is liable to occur. The length of time the wood should be steamed or boiled varies considerably, depending upon the size and "greenness" of the wood and the amount of preservative to be injected. In general, it is between 6 and 18 hours, although longer periods are sometimes used.

**Methods of Treatment and Their Selection.**—Many methods for treating piling have been tried but only a few have been found meritorious. Only those which have been most commonly practised are described.

**Bark Left on the Piles.**—Bark resists the attacks of the marine wood borers, but will adhere only a short time, after which it loosens and falls off. If the piles are to be driven untreated, however, the bark should be left on, except for the portion projecting above high-water level.

**Plank Coating.**—Strips of wood nailed tightly together around the pile will ward off attack for a short period, but their value is only temporary.

**Nail Coating.**—Flat-headed nails resembling upholsterers tacks driven into the pile close together will prolong the life of the pile. It seems that the iron rust formed by the nails is avoided by some of the marine borers, especially the limnoria. The method is, however, expensive and awkward and not recommended.

**Metal Coating.**—Sheets of zinc or copper nailed around the pile at those points subject to borer attacks will effectively protect the pile as long as they last. (See Plate XVIII, Fig. C.) Care should be taken, however, to make all joints tight. The coating will corrode in time and is liable to puncture by floating débris, but this method of treatment is efficacious.

**Burlap Coatings.**—These are made by coating the pile where it is subject to attack with various mixtures such as coal-tar, pitch, asphaltum, sand, etc., and wrapping the whole in several layers of burlap. Very good results have been secured from treatment of this kind.

**Cement Casings.**[1]—These are made in two ways, (1) with no space between the casing and the pile, and (2) with an intervening space of from 2 to 4 inches.

The first are manufactured as follows: The bark and knots are removed and the pile driven. A jacket of iron, wood, or sewer pipe is placed around it, and the space between jacket and pile, which is from 2 to 4 inches wide, is filled with hydraulic cement. (See Plate XVIII, Fig. D.) When this becomes hard, the jacket is removed. Some jackets are so made that they can be applied to the pile without disturbing the superstructure of the wharf, thus making repairs to broken casings easy.

The second class is composed of cement pipes divided longitudinally into two halves, which, when placed together around the pile, are joined by a scarf joint keyed with a wooden plug soaked in hot tar. The intervening space between pile and casing is filled with sand. The chief advantage of this kind of casing is the fact that broken sections can easily be replaced without removing the superstructure of the wharf. These treatments are very efficient.

**Electrolysis.**—A canvas bag or curtain is placed around the pile driven in position and an electric current passed through the pile and the surrounding water. This liberates chlorine gas in the salt water and kills the borers in the pile. It is necessary, of course, to apply this treatment from time to time, since it simply kills the borers present in the wood. The treatment is expensive, but performs a peculiar function in being able to protect piles already set in position and undergoing attack.

**Impregnation with Coal-tar Creosote.**—For general work, treatments with coal-tar creosote, by either the Bethell or Boiling process (see Chapter V for details of treatment), have given most effective results. It is necessary, however, to inject large quantities of the oil into the wood (18 to 24 pounds per cubic foot) if the piles are subject to severe attack. This greatly increases the cost of the treatment. However, piles properly treated in this manner have been known to last for 30 years, while untreated piles set in similar waters are completely destroyed in 5 years. While this method of treatment is the best known, it leaves much to be desired. It is, as has just been stated, very costly. Furthermore, several cases have been called to the author's attention where the piling so treated has not

[1] Circular 128, U. S. Forest Service.

withstood attack, especially of the limnoria and xylotria, and failed in less than 8 years after it was driven. There is a distinct need for a good preservative which can be used in treating piling set in waters badly infected with marine borers. (See Plate XIX, Figs. A and B.)

It seems that a more economical method of treatment than is now practised could be devised. As has already been pointed out, that portion of the pile driven below mud line needs no protection, yet in present methods it receives even more oil than the rest. Furthermore, the portion of the pile above high-water mark does not require as heavy injection as that portion in the water. If a plant could be constructed which could be tilted vertically after the piles are run into it, and only a portion of the pile impregnated, it is believed much expense could be saved. Such a plant would also be admirable for butt-treating poles under pressure.

The selection of the process to be used in treating piles largely depends upon local conditions. If the waters are comparatively free from borers, such as in our more northern harbors on the Atlantic Coast, or if the waters are brackish, a comparatively light treatment with creosote (10 to 14 pounds per cubic foot) is sufficient. If, however, the borers abound as at Gulfport, Miss., and San Francisco, Cal., the heaviest impregnations should be used. Where the piling can be protected from floating débris, casings of cement or metal as described above are also effective. These can also be placed over piling already driven into position if it is found attack is taking place. Treatments with burlap, soaked as already described, give good results even in waters badly infected. So far as is at present known, heavy impregnations with coal-tar creosote are, when all things are considered, the most effective that can be given, and they are recommended for all places where attack is severe.

**Cost of Treating Piling.**—The total cost of treating piling by the standard full-cell creosote process including the removal of the strips of inner bark or "skin" left after the piles have been

TABLE 28.—ESTIMATED COST OF TREATING PILING WITH CREOSOTE

| Item | Per cubic foot (cents) |
|---|---|
| Cost of peeling and handling at plant | 1.0–2.5 |
| Cost of preservative | 16.5 |
| Cost of treatment | 3.5–6.0 |
| Total cost of treatment | 21.0–25.0 |

roughly peeled in the woods is given in Table 28, where oil is figured at 9 cents a gallon of 8.75 pounds, the piles are steam-seasoned, and 16 pounds of oil per cubic foot are injected.

**Economy in Treating Piling.**—The cost of treating and driving piling as well as the life secured from it are all so variable that general figures are of value only as an illustration. In preparing the general estimates given in Table 29, two conditions are illustrated, case (A) where piling is driven in salt water where attack by marine borers is light, and case (B) where attack is severe. In the former it is assumed that a treatment of 16 pounds of creosote per cubic foot is given, while in the latter 22 pounds are injected. The cost of driving the piling including the superstructure bolted to them is taken as $6 per pile, and all piles are assumed to be 40 feet in length and to contain about 25 cubic feet each. Variations of at least 100 percent in the estimated annual savings either way can be expected because of the extremely varying conditions under which piling is used.

TABLE 29.—ESTIMATED ECONOMY IN TREATING PILING[1]

| Item | Case A | Case B |
|---|---|---|
| Life of untreated piling—years | 8 | 3 |
| Life of treated piling—years | 25 | 18 |
| Cost of untreated piling—driven in place | $8.50 | $8.50 |
| Cost of treated piling—driven in place | $14.75 | $16.50 |
| Annual charge—untreated piling | $1.32 | $3.12 |
| Annual charge—treated piling | $1.03 | $1.40 |
| Annual saving—treated over untreated | $0.29 | $1.72 |

**The Preservative Treatment of Wooden Boats.**—If wooden boats are used in salt water which contains marine borers, they are very subject to attack and unless properly protected their bottoms may be entirely destroyed in a year or less. For light boats which can be readily hauled out of the water, repeated coatings with copper paint will prove effective. Heavier boats should be protected with sheet copper nailed securely to the bottom. Barges and similar craft should have their bottoms built of lumber heavily creosoted, 12 or more pounds per cubic foot being injected. Even under these conditions, attack is very liable to occur. If fresh-water moorings are accessible the borers in the boats can be killed by anchoring the boats for a few days in fresh water.

[1] Interest compounded annually at 5 percent.

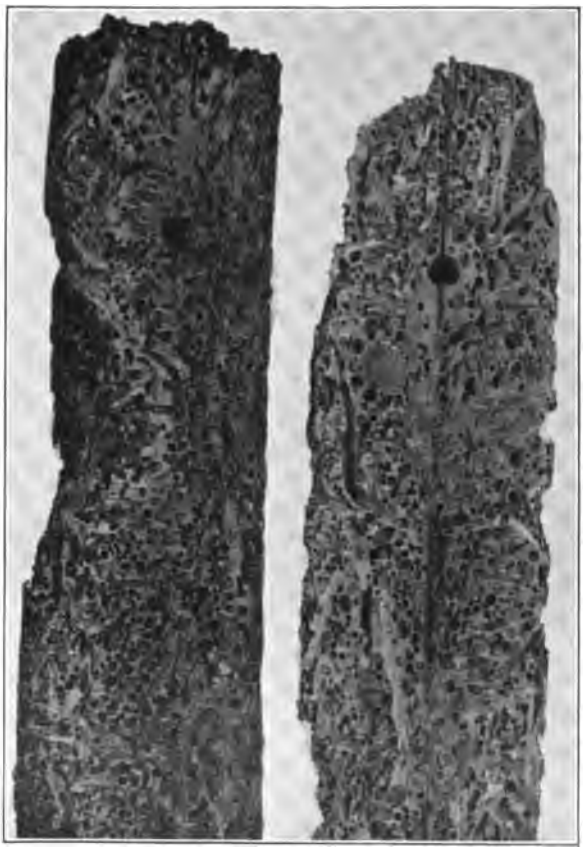

FIG. A.—Sections of longleaf pine piles after 21 months' exposure to the attack of marine borers at Gulfport, Miss. Section to the right, untreated; section to the left, impregnated with a crude oil. (Forest Service photo.)

(*Facing page* 186)

PLATE XIX

FIG. B.—Untreated pine piles completely destroyed by marine wood borers, Santa Rosa Island, Fla. (Forest Service photo.)

Wood in boats not subject to attack by borers is often quickly decayed, as the moist conditions of the air in them is very favorable to the growth of fungi. It is a very good plan to brush-treat with creosote or carbolineum all such joints subject to decay. The author has had considerable experience in protecting small fresh-water boats in this manner and has entirely eliminated decay. Of course, the portions so treated cannot be painted, as paint will not adhere to the creosoted wood. In barges and boats where artistic effects are not essential, all lumber subject to decay can be profitably creosoted by one of the empty-cell methods. This will protect the wood from rotting without increasing its weight very materially.

Although no cases are known of where it has been tried, it is believed that the life of small pleasure boats subject to decay can be materially prolonged if they are filled in the spring with a 3 percent solution of copper sulphate or a 1 percent solution of mercuric chloride and allowed to soak in this solution for several days before they are run into the water. These solutions should soak into the joints and permeate the partially decayed wood, thus killing whatever fungi might be present.

# CHAPTER XII

## PROLONGING THE LIFE OF MINE TIMBERS

On account of the warm damp air which exists in many mines, timber placed in them is very subject to attack by decay and insects. As the methods which will eliminate decay will also eliminate insects, no differentiation in treatment is specified. It is very common for mine timbers, a foot or more in thickness, to become completely decayed in less than 2 years if set untreated. The expense of resetting these timbers is great, and, furthermore, such replacements generally interfere with the working of the mine. This is particularly true in coal and iron mines. In many mines the walls are of solid rock so that little timber is necessary, and even this is often not subject to rapid decay. Also, in temporary workings, where the props are either left standing or "pulled" after the coal or ore has been removed, a preservative treatment is unnecessary. But for permanent shafts and gangways it is highly advisable to so treat the timbers that greatest life can be secured from them and thus the working of the mine will be least interfered with. Several mine companies in the United States are using treated timber and have secured excellent results. As the workings are extended deeper and deeper, the need for a preservative treatment is found to become more acute.

**Selection of Species.**—It is the practice at most mines to use any kind of wood which is available and is large enough for the purpose desired. Preference is, of course, given to those varieties which are most durable. This freedom in the selection of species must be considered bad practice on the part of the mine operator, for aside from the large expense and trouble to which he is put in replacing the decayed timber, he is filling his mines with the mycelia of the destructive fungi. Sanitation of timber in such conditions is advisable if contamination is to be prevented, just as it is among human beings where some are affected with a contagious disease.

Strength, form, and durability are the inherent properties

required of a good mine timber, but if a preservative treatment is to be given, adaptability to treatment can be substituted for natural durability. As mine timbers, except for shafting and "long walls," are generally short, they are not so difficult to furnish as timber for poles and piles, and consequently the mine operator has a wider choice of species at his command. If the timbers are to be set untreated, durable woods should be selected for the permanent workings, such as osage orange, black locust, white oaks, chestnut; or if strength is not so important, the cedars, cypress, etc. The more heartwood they have the longer will be the life secured.

When treated, the red oak, maple, birch, beech, the hard pines, fir, elm, etc., are good woods where great strength is required, and for workings requiring less strength most any wood having an inch or more of sapwood can be used to advantage.

**The Manufacture of Mine Timbers.**—In permanent workings, whether the timbers are to be set treated or untreated, they should be peeled before they are placed in the mine. This in itself will increase their durability and destroy the breeding places for many wood-destroying insects. To peel timber in the woods or at the shipping point effects a saving in freight and in the cost of handling. The weight of the bark usually amounts to from 6 to 15 percent of the original green weight. If the timbers are to be treated, they should be framed to exact dimensions so that no cutting into the treated surface will be necessary. Unless there is some good reason to the contrary, all timbers intended for treatment should be left round. Slabbing them only exposes the heartwood and hence decreases the effectiveness of the treatment.

**Methods of Seasoning.**—When mine timbers are set untreated there is little or no advantage gained in seasoning them before placing them in the mine. If they are to be treated, however, seasoning is advisable, as it enables better results to be secured. Air seasoning is recommended, unless for some local reason it cannot be practised. Props and other round timbers can be piled on skids in the same manner as poles (see Chapter IX). Mine ties can be piled like railroad ties (see Chapter VIII). Lumber and sawed stock should be piled with liberal air courses between the planks, and with as small an area as possible in contact. The rules as given in Chapter IV for the selection and care of the seasoning yard should be followed.

The length of time necessary to air season the timbers of course varies considerably (see Chapter IV). In general, 1 or 2 months are sufficient. Fig. 23 shows the rate at which loblolly pine and red oak props and ties air-seasoned in Pennsylvania and Alabama. Whenever possible, timber should be seasoned before shipment, as a considerable saving in freight will result. If it is not practicable to air season the timber, it can be seasoned in steam or oil as described in Chapter IV. The length of time necessary to do this will, of course, vary with each kind and form of

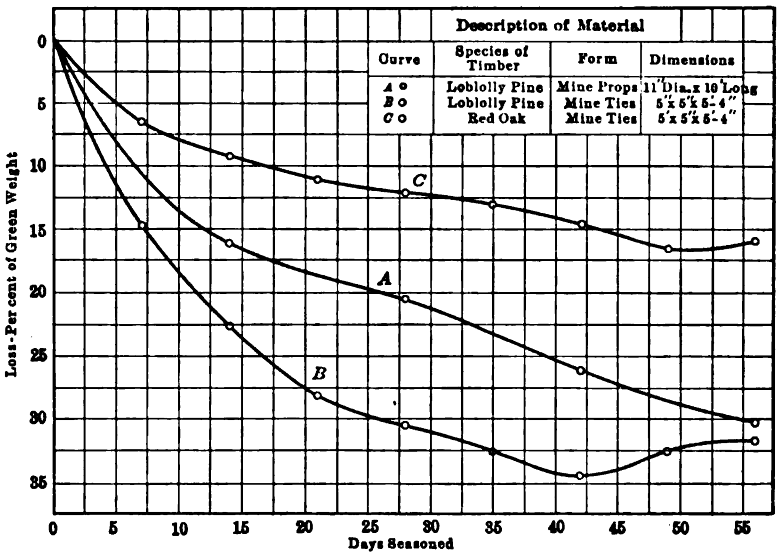


FIG. 23.—Percentage of green weight lost by seasoning mine timbers.

timber and with the character of treatment desired, so that each plant will have to work out its own best operative conditions. The instructions already given in Chapters IV and V should be consulted for helpful suggestions.

## METHODS OF TREATMENT AND THEIR SELECTION

**Mine Ties.**—The methods of treating mine ties do not differ in any essential way from the treatment of cross-ties described in Chapter VIII. If the mines are dry, treatments with zinc chloride or any empty-cell treatment with creosote will prove very satisfactory. On the other hand, if the ties are liable to be wet or alternately dry and wet, heavier injections of

[1] From Bulletin 107, United States Forest Service.

creosote are best. Ties constantly in water need no treatment whatever.

**Mine Props.**—Under this heading are included props, legs, collars, and caps. The cheapest treatment consists in brush-treating these with coal-tar creosote, and if the preservative is applied to the ends and joints as well as the sides, several years increase in life will be secured, so that the cost of the operation will more than pay for itself. Such treatments should, of course, be applied to the timbers before they are placed in the mine. If dipped, better results will be secured than by brush-treating, as all checks will be coated with the preservative.

Impregnation treatments have given by far the most satisfactory results. Three processes are recommended, the Burnett, the empty-cell and the full-cell creosote. If decay is not unusually severe and if the timbers are liable to be broken by crush or "squeeze," the Burnett process is recommended. Excellent results can be secured from it. If the timbers are set in mines where there is much moisture and where decay is very rapid, treatments with creosote should be used, the empty-cell method being employed for porous woods containing much sapwood, as loblolly and shortleaf pines, etc., and the full-cell process where the timbers are refractory and the percentage of sapwood small, as in Douglas fir, hemlock, and hewed timbers generally. One-half pound of zinc chloride per cubic foot is sufficient for the Burnett-treated timbers. Six to 12 pounds per cubic foot is sufficiently heavy for the creosoted timbers. All these timbers ean be handled in precisely the same manner as in treating ties.

The practice of sawing off treated mine timbers in order to make them fit is bad. It can often be avoided by using comparatively short timbers and wedging them into place by means of creosoted wedges or caps. In this manner much valuable timber can be saved and decay greatly retarded.

**Square Sets.**—If these are made of round timbers they can be handled in the same manner as props. If the timbers are sawed or hewn and are not susceptible to treatment, the full-cell creosote treatment is recommended. Care should be taken to see that the ends especially are well protected, and if for any reason it is necessary to retrim these timbers after they have been treated, such places should be brushed over with one or more coats of creosote.

**Lagging.**—It seldom pays to treat lagging, but if the lagging is made of sawed lumber, a treatment with zinc chloride can profitably be given. The chief advantage in treating lagging rests in retarding the spread of the wood-destroying fungi.

**The Treatment of Mine Timbers in Relation to Fire.**—This is a very important matter, as nothing should be placed in the mines which will increase the fire hazard. All timbers treated with zinc chloride will be more fire resistant than untreated timbers. Furthermore, this salt tends to keep the timbers moist, and hence under pressure they will act more like green timber, viz., bend considerably before they break. Much importance is attached to this property by some mine operators, as it gives a warning to the men in case of a crush or fall of rock or earth.

In all cases, timbers which are creosoted should first be air seasoned for at least 1 month before they are placed in the mines. This will enable the lighter portions of the oil to evaporate and will decrease very materially the ease with which the timber can be ignited. After it has once air seasoned, creosoted timber is not easily ignited. It is possible to hang the naked flame of a miner's torch or lamp on such timber without injury other than a charring of the surface. If, however, the timber once ignites, it will burn freely and, unfortunately, emit dense clouds of black smoke. Fire in creosoted timber is, however, easily extinguished. The author witnessed the effect of a fire in a mine shaft, built of half untreated and half creosoted props, where the flames shot from the mouth of the shaft. The fire was extinguished by smothering the shaft. An examination made after the fire showed nearly all of the untreated props destroyed, while those creosoted were simply charred on the surface and still serviceable. There is little doubt, however, but what zinc-treated timbers in mines are preferable to creosoted timbers when judged from a fire-hazard standpoint. They are not only fire resistant in themselves, but they do not emit odors which may be objected to by the workmen and hence cause anxiety among them. For further information on the inflammability of timber treated with zinc chloride and creosote, the reader is referred to Chapter XVI.

**Cost of Treatments.**—Table 30 gives an estimated cost of treating mine timbers. It is assumed that creosote costs 1 cent per pound, zinc chloride 4 cents per pound, peeling and seasoning about 1 cent per cubic foot, brush-treating about 15 cents per

FIG. A.—Gangway of treated mine timbers, Pottsville, Pa. (Forest Service photo.)

FIG. B.—Rank growth of fungus on mine timbers.

(Facing page 192.)

PLATE XX

FIG. C.—Treated and untreated mine props. Treated prop to right set at same time as failed untreated prop at left, Pennsylvania. (Forest Service photo.)

FIG. D.—Untreated mine props destroyed by decay and "squeeze,' Pennsylvania. (Forest Service photo.)

set, and impregnating about 2 cents per cubic foot. A sufficiently close estimate on the cost of treating mine ties can be secured from a direct comparison with cross-ties already given, making allowance, of course, for the differences in volume between the two.

TABLE 30.—ESTIMATED COST OF UNTREATED AND TREATED PINE GANGWAY SETS

(One set consists of one 7-foot collar, one 9-foot leg, and one 10-foot leg; average diameter of timber about 13 inches)

| Method of treatment | Amt. of preservative used per set | Cost of preservative | Cost of peeling, seasoning treating | Total cost of set in mine |
|---|---|---|---|---|
| | lb. | $ | $ | $ |
| Unpeeled | | | | 8.50 |
| Peeled and seasoned | | | 0.26 | 8.76 |
| Brush-treated—creosote | 28 | 0.28 | 0.40 | 9.18 |
| Empty-cell process | 130 | 1.30 | 0.80 | 10.60 |
| Full-cell process (Bethell) | 312 | 3.12 | 0.80 | 12.42 |
| Burnett process | 13 | 0.52 | 0.80 | 9.82 |

In western United States the cost of treating mine timbers is high. Some figures secured from practice in Montana in treating square timbers are as follows:[1]

Cost of untreated sets:

| | |
|---|---|
| 1127 feet B.M. squared timbers, at $20.50 per M B.M. | $25.36 |
| Framing timbers | 13.50 |
| Cost of lagging, at $15 per M B.M. | 5.90 |
| Switching and unloading charges | 0.85 |
| Cost of placing set | 18.00 |
| Total cost of untreated set in place | $63.61 |

Cost of treatment:

| | |
|---|---|
| Cost of treating, including interest, depreciation, fuel, and labor charges | 3.34 |
| Cost of creosote, at 15.6 cents per gallon; absorption 4.5 pounds per cubic foot | 8.03 |
| Loading and unloading charges | 1.23 |
| Total cost of treatment | 12.60 |
| Total cost of treated set in place | 76.21 |

**Ecomony of Treatments.**—Because of the rapidity with which timber placed in most mines decays, the economy due to its treatment is very striking. As stated in the opening of this chap-

[1] Bulletin 107, United States Forest Service.

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ter, it is not advisable to treat all of the timber which is placed in the mine because much of it is intended to serve only a short period. But for permanent shafts, gangways and entries it will almost invariably be found that a treating process of some sort is advisable and will result in a marked economy. Fortunately, some reliable records on the life of treated timber in mines is available on which fairly accurate estimates of economy can be based. (See Chapter XX, Reliable Records on the Life of Treated Timbers.) Excluding all failures from crush and fire, which may be nil or total, the economies that may reasonably be expected when such woods as pine, red oak, etc., are used are shown in Table 31.

TABLE 31.—ESTIMATED ANNUAL CHARGES OF TREATED AND UNTREATED MINE SETS

(Interest 5 percent compounded annually)

| Method of treatment | Life of timber (years) | Cost of timber set in mines | Annual charges |
|---|---|---|---|
| Untreated | 2 | $8.50 | $4.39 |
| Brush-treated—creosote | 5 | 9.18 | 2.12 |
| Burnett process | 10 | 9.82 | 1.27 |
| Empty-cell process | 11 | 10.60 | 1.27 |
| Full-cell process (Bethell) | 15 | 12.42 | 1.19 |

# CHAPTER XIII

## PROLONGING THE LIFE OF PAVING BLOCKS

**Progress of Wood Paving.**—"The first use of wood for paving is said to have been in Russia, where crude blocks were laid several centuries ago. Wood was introduced into New York City in 1835–36, and into London in 1839. Continental Europe was slower to take it up.

During the first 30 years of wood paving in England and America the chief consideration seems to have been the form of block. The large and unequal interstices between the round blocks then commonly used permitted the edges to wear off rapidly into a corduroy condition which was uncomfortable to the traveler, and which hindered both drainage and cleaning, thus making the pavement unsanitary and hastening its decay. To remedy this, other forms of block were devised, many of which were patented.

In the United States perhaps the most conspicuous of these blocks was the 'Nicholson,' patented in 1848 and laid extensively in the 10 years following the civil war. The block was rectangular, which gave equal interstices; but this by no means solved the problem, and results were no better than before. Little thought was given to the kind of wood used, and as soft a wood as white pine was frequently laid. The blocks were neither seasoned nor treated with chemical preservatives, and quickly decayed. Wide joints permitted water to get under the pavement, where it was absorbed by the blocks, with the result that they swelled, so that the pavement often heaved from its foundation. Finally, the foundation was usually of untreated planks, laid directly upon earth, so that they soon decayed, while the pavement sank into ruts and holes.

Round blocks, mostly of cedar, were extensively laid in the Middle West. They made neither a durable pavement nor in any way a satisfactory one. But they were cheap and served a good purpose in tiding fast-growing cities over a critical period. There have also been laid in various cities pavements of oak, cypress, white pine, hemlock, Washington red cedar, cottonwood, mesquite, Osage orange, redwood, Douglas fir, and tamarack. In nearly all these cases the blocks were untreated, or at most dipped or boiled for a short time in tar, asphalt, or other mixture of supposed preservative value, and they failed to give satisfactory results. Untreated American red gum was tried in England, and for a time raised great hopes, but it finally proved unsatisfactory.

Some species of eucalyptus, especially karri (Eucalyptus diversicolor) and jarrah (E. marginata), which are very dense, hard, Australian woods, have been laid extensively in England. In London these woods have shown a life of from fifteen to twenty years, but continued use has not entirely justified the hopes first entertained for them. Their structure is too dense to permit impregnation with chemical antiseptics, without which they absorb water and swell. They wear much more slippery than most native woods, and they are not immune from decay, though because of certain antiseptic gum-resins which they contain they are more so than any untreated native woods. In England, however, they are still used. Jarrah blocks were laid on Twentieth Street, New York City, in 1895, but were removed in 1904. The cost of this pavement was about $5 per square yard, which would exclude these woods from extensive use in America even should they make a better pavement than our best creosoted native woods, which is not likely."[1]

The failure of the untreated woods turned attention to blocks artificially preserved. One of the earliest records in our country is in the city of Galveston, Texas, which laid some creosoted pine blocks in 1873. These blocks gave satisfactory service for 30 years, when they were destroyed by a flood. Little progress was made in advancing the use of wood blocks until within the past 10 years, when the demand for a high-class pavement, especially in large cities, caused a big increase in the number laid. This growth is shown by the following table:

TABLE 32.—AMOUNT OF WOOD USED ANNUALLY IN THE UNITED STATES FOR PAVING BLOCKS

| Year | Amount of wood used—cubic feet[a] |
|---|---|
| 1907 | 2,874,560 |
| 1908 | 1,260,020 |
| 1909 | 2,994,290 |
| 1910 | 4,692,453 |
| 1911 | 10,145,724 |
| 1912 | 7,397,095 |

[a] = divide figures given by 2.625 to convert into square yards.

Mr. George W. Tillson, Chief Engineer, Bureau of Highways of New York City, conducted an inquiry on the comparative value of various forms of pavements in which the opinions of several city engineers were asked in regard to the salient points to be considered in judging a street pavement. Mr. Tillson summarized these opinions in his book entitled "Street Paving

[1] Extract Circular 141, United States Forest Service.

and Paving Materials." The results of this investigation are given in Table 33.

TABLE 33.—COMPARATIVE VALUE OF DIFFERENT PAVEMENTS

| Pavement qualities | Percentage | Granite | Sandstone | Asphalt (sheet) | Asphalt (block) | Brick | Macadam | Creosoted wood |
|---|---|---|---|---|---|---|---|---|
| Cheapness (first cost).. | 14 | 4.0 | 4.0 | 6.5 | 6.5 | 7.0 | 14.0 | 4.5 |
| Durability............ | 20 | 20.0 | 17.5 | 10.0 | 14.0 | 12.5 | 6.0 | 14.0 |
| Ease of maintenance... | 10 | 9.5 | 10.0 | 7.5 | 8.0 | 8.5 | 4.5 | 9.5 |
| Ease of cleaning....... | 14 | 10.0 | 11.0 | 14.0 | 14.0 | 12.5 | 6.0 | 14.0 |
| Low traction resistance. | 14 | 8.5 | 9.5 | 14.0 | 13.5 | 12.5 | 8.0 | 14.0 |
| Freedom from slipperiness (average of conditions)............. | 7 | 5.5 | 7.0 | 3.5 | 4.5 | 5.5 | 6.5 | 4.0 |
| Favorableness to travel | 4 | 2.5 | 3.5 | 4.0 | 3.5 | 3.0 | 3.0 | 3.5 |
| Acceptability......... | 4 | 2.0 | 2.5 | 3.5 | 3.5 | 2.5 | 2.5 | 4.0 |
| Sanitary quality....... | 13 | 9.0 | 8.5 | 13.0 | 12.0 | 10.5 | 4.5 | 12.5 |
| Total number of points | 100 | 71.0 | 73.5 | 76.0 | 79.5 | 74.5 | 55.0 | 80.0 |
| Average cost per square yard, laid, 1905...... | ..... | $3.26 | $3.50 | $2.36 | $2.29 | $2.06 | $0.99 | $3.10 |

Favorableness to travel is dependent chiefly upon smoothness and freedom from dust and mud, secondarily upon the qualities composing "Acceptability."

Acceptability includes noise, reflection of light, radiation of heat, emission of unpleasant odors, etc. It chiefly concerns the pedestrian and the adjoining resident.

Cost per square yard includes concrete, but not excavation, curbing, etc.; except for macadam, which is not usually laid on concrete.

Other investigators have attempted similar comparative studies, and while no two of them agree in all respects, a high rating is given to wood-block pavement in regard to its noiselessness, durability, and sanitation.

On the other hand, the pavement has been severely criticized on account of its high initial cost and troubles experienced with slipperiness, expansion or buckling, and the exudation of oil, or "bleeding." From investigations which have been conducted, it is believed that much progress has been made in overcoming some of these objections and that before long all of them, except perhaps high initial cost, will be eliminated.

**Selection of Species.**—At present most of the wood blocks used (over three-fourths of the total number) are cut from the "southern yellow pine." This is rather indefinite as regards the exact species, as the term may include the longleaf, shortleaf, Cuban, or even loblolly pines. What is wanted, undoubtedly, is the longleaf pine, but according to present practice there is no certain way of telling these various pines apart except by a most careful microscopic examination, which in commerical work is,

of course, impracticable. Specifying a certain number of rings per inch is of assistance but is by no means certain. As the strength of wood is directly proportional to its dry weight, it is believed that a specification coupling rings per inch with dry weight would give the engineer more definitely what he desires. Branding lumber at its point of production would also be of assistance to the inspector.

In addition to the "southern yellow pine," blocks made of Douglas fir, red gum, tamarack, larch, and Norway pine are also used, although in comparatively small amounts.

The intrinsic properties demanded of a good block wood are resistance to wear, uniformity in structure and freedom from defects, adaptability to treatment, and ability to hold its shape after treatment. These requirements coupled with a reasonably low cost limit very materially the number of woods which can be used. In addition to the woods already mentioned, it is believed the following are worthy of trial: Beech, birch, black gum, maple sycamore, tupelo, hemlock, lodgepole and western yellow pines. They will, of course, have to be handled somewhat different from standard practice, but some of them possess desirable qualities for street pavements.

Blocks which are cut from a very hard wood have a tendency to wear smooth, so that unless the pavement is sanded periodically they may prove too slippery for satisfactory use. If some of the woods above suggested give good service in pavements, it should tend in certain cases to lower the initial cost of wood-block pavements.

**The Manufacture of Paving Blocks.**—Paving blocks are usually cut from planks of varying lengths, about 3 1/2 to 4 inches thick, and 6 to 10 inches wide. These are fed into the paving-block machine, which is fitted with a series of saws so spaced as to cut the blocks to exact depth. In this manner many blocks are cut at one time. The capacity of the machine varies but good machines can turn out 200 square yards of 4-inch blocks per hour. On leaving the block machine, the blocks fall onto a conveyor, where they are inspected and all imperfect ones removed. The rest are carried mechanically to the treating cylinder or cylinder cars and dumped automatically. It is very important that the blocks be cut to an exact depth, for if this is not done the surface of the pavement will be uneven and its wear greatly augmented. The prevailing depth of blocks for street

work varies from 3 to 4 inches, the smaller being used for light and the larger for heavy traffic. In Europe the practice is to use deeper blocks than in our country. This, of course, greatly increases the cost of the pavement but is claimed to give longer life and greater resilience. It is believed that the question of proper depth of the block is not given the attention to which it is entitled. As all woods vary in strength, it is only reasonable to cut them to different depths depending upon their strength. Blocks are laid with the grain vertical. This subjects them to shear parallel to the grain, which is the weakest direction in which a load can be applied. Failure from shear is therefore great, and many blocks have been shattered in practice because of such failure. It is believed, therefore, that if best service is to be secured, blocks low in shear should be cut to greater depths than blocks which are high.

The planks from which the blocks are cut are generally air seasoned. It is believed unnecessary to do this, in fact sometimes inadvisable. If cut from green planks, the blocks will be treated at their maximum size, so that danger from expansion after they are placed in a street will be lessened. Most woods treat easiest in the direction of the grain, so that the problem of securing a good penetration in blocks only a few inches in length is not a difficult one.

Specifications for paving blocks vary considerably. The following is a fair sample of what is generally required: The blocks shall be made of prime, sound timber, and no wood averaging less than 6 rings to the inch, measured radially from the center of the heart shall be used or wood that is poorly manufactured and contains loose knots, worm holes, and other defects. The blocks shall be from 5 to 10 inches long, 3 to 4 inches in depth parallel to the grain depending upon traffic, and 3 to 4 inches in width, provided all blocks furnished for one street are of uniform width and depth. A variation of 1/16 inch in depth and 1/8 inch in width will be allowed.

**Methods of Treatment.**—Nearly all of the paving blocks treated in the United States are impregnated with coal-tar creosote, either alone or in mixture with tar, by the full-cell method. In a few cases, the blocks are simply dipped in oil (creosote or carbolineum) and lately the zinc-creosote process has been advocated for blocks used in factories and shops. A common method consists in placing the air-seasoned blocks in a

treating cylinder (and sometimes drawing a vacuum), after which the oil is admitted and forced into them under a pressure of about 150 pounds per square inch until the desired amount is absorbed. The cylinder is then drained of excess oil and a vacuum drawn for about 1/2 hour to dry the blocks, after which they are removed and are ready for use. This practice is modified by certain operators, who steam the blocks after they are run into the cylinder and then pull a vacuum after the steaming period. A few operators also steam the blocks after they have been impregnated with the oil.

The amount and kind of oil injected varies considerably. Nearly all specifications call for a heavy grade, viz., one with a specific gravity of at least 1.08 at 25° C. and in some cases as high as 1.12. Many engineers allow the oil to be mixed with certain amounts of "filtered tar" in order to bring up its gravity. Some also allow water-gas-tar creosote to be mixed with the coal-tar creosote. The amount of oil required is generally 16 pounds per cubic foot, although this varies from 12 to 20. It can thus be seen that the practice in treating blocks is by no means a uniform one, but differs with the opinions of the various engineers.

The Chicago Creosoting Company has recently constructed a block plant wherein the cylinders are placed vertically. (See Plate XI, Fig. D.) The blocks are dumped into the top of the cylinders by a mechanical conveyor. After the desired absorption has been obtained, the excess oil is drained from the cylinders, and a door in the bottom of the cylinder is opened allowing the blocks to fall directly into cars ready for shipment. This method does away with cylinder cars entirely and is claimed to cut down the cost of handling.

**Troubles Experienced with Wood-block Paving.**—It has already been stated that wood-block paving at times has serious objections. Unfortunately, the exact cause of these difficulties is not known at present, so that definite remedies for all conditions cannot be prescribed. Opinions and practice differ widely. The chief objections are slipperiness, exudation of oil, and expansion of the blocks.

*Slipperiness.*—In general, the harder the blocks the smoother the pavement becomes. Blocks of softer wood give, therefore, less trouble from slipperiness, but there is a limit to which the softness can go, as blocks which are too soft will of course wear rapidly.

Oil and tar on the surface of the pavement also increases slipperiness. It is believed that this cause can be largely overcome as will be discussed below.

If our streets were sanded from time to time, as is done abroad, the surface of the blocks would become roughened because the sand would embed itself in the wood. This should be done particularly in cold weather, when ice forms on the pavement. Asphalt is also subject to the same objection in cold weather and a similar treatment should be given it.

*Exudation of Oil.*—This is about the most troublesome objection raised against wood blocks. The oil and tar may at times exude to the surface and form a thick, disagreeable mat, which sticks to the feet of pedestrians and is generally objectionable. In certain cities like Chicago, the trouble became so acute as to arouse bodies of citizens into a protest against what was termed the "black plague." Other cities like Minneapolis have fortunately been free from these troubles. It is probable that the exudation of oil, commonly called "bleeding" or "weeping," is due to several causes, such as too heavy an impregnation, too much pitch or tar poured into the joints, too rapid-grown blocks, improper treatment, and too close laying of the blocks. From observations and tests made by the author it is believed that bleeding can be eliminated if (1) only slow-grown wood is used for the blocks; (2) if green timber or steamed seasoned timber is used; (3) if a strong preliminary and final vacuum is drawn before and after the oil is injected; (4) if when tar is used the blocks are steamed slightly after the oil is injected; (5) if the penetrations are made complete; (6) if impregnations no greater than 16 pounds per cubic foot are given; (7) if straight coal-tar creosote or coal-tar creosote containing only small amounts of carbon-free tar is injected; (8) if the blocks are not laid too close together; (9) if excess tar or pitch is not poured between the joints. All of these requirements can be easily met without added cost.

*Expansion of the Blocks.*—This is commonly called "mushrooming," "buckling," or "pop ups." (See Plate XXI, Fig. A.) The true cause of it is not known except, of course, that the blocks are under heavy pressure. If the blocks are laid very dry and close together there will be little room for expansion and the pavement will be very liable to buckle. It is believed that if the blocks are well penetrated so that their tendency to absorb

moisture will be decreased, are treated green or steam seasoned, are laid fairly loose and have proper expansion joints, little or no trouble from buckling will be experienced.

It is wasted effort to try and make the blocks nonexpansive, for no matter how much oil is forced into them they will absorb more or less water in time. Furthermore, the oil and wood will expand due to rise in temperature. Best practice, therefore, is to keep the absorption of water to a minimum by proper treatment and to allow for expansion by carefully laying the pavement as described above.

**Method of Laying Wood Blocks.**—In street work, a concrete base about 4 to 8 inches thick is first constructed, this having the desired crown. Over this is then placed a layer of coarse sand about 1 inch thick. The blocks are then laid on this smoothed sand cushion, after thich they are tamped and rolled into final position. Asphalt, grout, or hot pitch is then poured into the joints and further worked into them with a squeegee. The surface is then covered with sand and the pavement is ready for use. In a few days the excess sand is removed from the pavement.

Experiments have been tried in doing away with the sand cushion by pouring hot pitch directly over the concrete base and embedding the blocks in it. These pavements have not been in service sufficiently long to judge of the results.

The angle at which the blocks are laid has also been tested. It is found that blocks laid at an angle of 671/2° with the curb show least wear, those at 45° next, and those at 90° most.

The character of filler to be used is still an open problem. Coal-tar pitch and asphalt seem to be preferred. The former is objectionable in that, if not properly applied, it will ooze to the surface. Asphalt is free from this objection but is more difficult to work into the joints.

Expansion joints are, at times, laid not only along the curb (about 1 inch in width on a 50-foot roadway) but crosswise.

In some cities strips of wood about 1/4 inch thick are placed between the blocks, thus leaving joints for a better footing of horses. This practice, however, is not common.

When wood blocks are used on certain types of bridges, they are laid directly upon creosoted plank. This adds considerably to the lightness of the bridge and is considered a distinct advantage over other forms of pavement.

**Cost of Treatment.**—The cost of treating wood paving blocks

FIG. A.—A "popup," or failure in a street laid with creosoted blocks due to their expansion.

FIG. B.—Wood block pavements—grading the sand cushion and laying the blocks, Minneapolis, Minn. (Forest Service photo.)

(*Facing page* 202.)


FIG. C.—Working the tar filler into the joints of a newly laid wood block pavement. (Forest Service photo.)

FIG. D.—Pine beams in a building completely rotted in the end after 30 years' service, Madison, Wis.

varies with the kind of oil specified, the amount to be injected, the kind and size of the block, and other peculiarities in the specifications. If ordinary creosote is used it can be obtained for about 8 cents per gallon. Generally, however, a higher grade is required, which in some cases costs 12 to 15 cents or more per gallon. Assuming the cost of the oil to be 1 cent per pound and 16 pounds to be injected per cubic foot, the cost of treating a square yard of 3 1/2-inch blocks will be about 45 to 50 cents, and of 4-inch blocks about 52 to 57 cents. This, of course, is but a fraction of the total cost of the pavement, which, in general, varies from about $2.20 to $3.70 per square yard, making it one of the most expensive pavements in use.

**Advantages of Wood-block Paving.**—Wood-block pavements possess some very desirable properties, the chief ones being sanitation, durability, ease of repair, low traffic resistance, ease of cleaning, and absence of noise. Friends of the pavement will find many other points to extoll, but the above list may be considered conservative.

Coal-tar creosote is a strong antiseptic, and as large quantities of it are forced into the blocks, its presence alone tends to keep the street in a healthy, sanitary condition.

The durability of wood blocks when properly laid is surprising. Data collected on a test pavement in Minneapolis, where accurate traffic records are kept over one of the busiest streets in the city, show a wear of about 1/32 inch per year. The experiences of several cities have shown the marked value of wood blocks in comparison with the durability of other kinds of pavement. There is no doubt but what the good results already obtained could be considerably bettered if American municipalities only took better care of their pavements. In this respect Europe is far ahead of us.

The ease with which wood-block pavements can be repaired is all the more reason why better care should be taken of them. If a depression once starts it will grow rapidly until a considerable hollow is formed. The time to repair such failures is in their beginning when all that is necessary is to remove a few blocks, smooth the sand cushion, and add new ones.

The depressions caused by vehicles and horses in asphalt on hot days is well known. This, of course, means the load is harder to pull. Wood blocks do not have this objection and because of their smooth surface make traffic run smooth.

The even surface of wood-block pavements enables them to be easily cleaned and, of course, adds to their santitation.

It is perhaps the noiselessness of wood blocks which makes them so desirable, especially in congested business districts, and has earned for them the title of the "silent pavement." This quality has placed wood-block pavements in high regard and is largely responsible for their rapid growth in our large cities.

In all of the above, it has been assumed that the pavements were properly laid, for if this is not done poor results are bound to follow. There is no unusual difficulty in properly laying a wood-block pavement.

**Wood Blocks for Barns, Factories, Etc.**—Considerable progress has been made within the past few years in introducing wood-block flooring in factories, car barns, ferry ships, etc., where it has given good service. It is liked by the workmen in preference to cement floors because of its "touch." It is durable, easily repaired, sanitary, and dustless. For use under such conditions the blocks are often cut smaller and treated with less oil than blocks intended for streets. In fact, the Rueping and Card processes are sometimes employed, thus decreasing perceptibly the cost of treating the blocks. The blocks are laid in much the same manner as for street work except that the angle of the courses is almost invariably 90°.

# CHAPTER XIV

## PROLONGING THE LIFE OF SHINGLES

Shingles are subject to common forms of destruction, (1) decay and (2) fire. If made from durable woods, the problem of protection from decay is not serious, as shingle roofs may easily last 25 years or more. Protection from fire is of greater importance, especially where the houses are close together. In congested districts the use of shingles is now almost entirely obsolete. However, shingle roofs possess certain desirable properties so that their use in dwellings will undoubtedly continue to be extensive.

**Selection of Species.**—In round numbers about 15 billion shingles are used annually in the United States, about 75 percent of which are of cedar—mostly the western red cedar of Washington. Next in rank come cypress and yellow pine, each furnishing about 9 percent. Then redwood with 3 percent, white pine 2 percent, and spruce 1 percent. The other species such as chestnut, hemlock, western pine, and oak all furnish less than 1 percent. With the exception of oak and chestnut, the total cut of which is insignificant, it will be noticed that all of the shingles are made from coniferous woods.

The ideal shingle is one which is light in weight, durable, and will "lay flat" without checking, warping, or splitting. Western red cedar admirably meets these requirements. Excellent service is also secured from cypress and redwood shingles, both of which possess remarkable durability.

The best grades of shingles are cut only from clear timber free from all defects. Sapwood is also excluded, since it is not very decay resistant. If, however, the shingles are given a thorough preservative treatment, sapwood should not be considered a defect, and in some cases treated sapwood shingles can be obtained at no greater cost than untreated shingles of all heartwood.

### METHODS OF TREATING SHINGLES

**Treating against Decay.**—The most common method of protecting shingles from decay is to dip them in a preservative and

after they have dried nail them on the roof. There are several preservatives sold on the market for this purpose under the name of "shingle stain," which not only preserve the shingle but color it. For best results, the shingles should be thoroughly air dry when they are dipped and the preservative should be warm or even hot. As a general rule, only that portion of the shingle which is exposed is dipped, the upper or thinner portion being in this manner covered by the treated portion of the shingle next above it on the roof. Roofs laid in this manner are frequently given a final coating of preservative after they are laid, in order to insure a uniform color and the treatment of all exposed portions.

Cheaper and less efficient results are obtained if the shingles are simply brush-treated with the preservative after they are laid. It is doubtful if ordinary paint preserves the life of shingles; in fact, it may hasten their decay. Paint is of value, however, in certain cases, in that it tends to make the shingles lie flat and hence prevent leaks.

Most efficient results in treating shingles against decay consists in impregnating them with the preservative. This is done either in open tanks or pressure plants. The absorption of the preservative should not be so great as to unnecessarily increase the cost of the shingles or cause them to ooze and drip oil on hot days. An absorption of 10 pounds per bundle is ample. In either of these processes the shingles can be treated in the bundle, provided they are not strapped too tight together. If the open-tank process is used the shingles should be removed while hot; if the pressure process is used, a final vacuum should be drawn. These manipulations are advisable in order to dry the shingles. If treated in this manner sap shingles can be made as resistant to decay as heart shingles, and inferior shingle woods like hemlock and yellow pine made exceedingly durable.

Shingles treated with creosote or the so-called shingle-stains have a very strong odor which to many people is objectionable. This odor, however, decreases with age and in time ceases entirely. Furthermore, the rain-water off a freshly treated roof is very liable to smell and taste of the preservative at least until the roof has been exposed for several weeks.

**Treating against Fire.**—Practically nothing has been done to date in treating shingles against fire. The recent agitation against shingle roofs in certain cities, has, however, caused considerable

interest in this matter and several concerns are now at work attempting to render shingles noncombustible. Ordinary fireproofing compounds like ammonium chloride, ammonium phosphate, etc., are objectionable in that they are soluble in water and consequently will soon be washed from the wood. It is possible, however, that their use might be rendered practicable by painting the shingles treated in this manner with a waterproof paint after they have been laid. A large variety of experiments are now under way, some of which indicate hope of a satisfactory solution of the problem, but at this writing no method that can be called successful is known. Greatest danger from fire is caused by the shingles curling and igniting from sparks or brands. If the shingles are made to lie flat their liability to catch on fire from such sources is greatly decreased. Some of the so-called "fireproof" paints now on the market are of value in this respect and tests known to the author have indicated that even ordinary paint will be found of material assistance.

**Cost of Treating Shingles.**—If shingles are impregnated with creosote, the cost will be about \$1.25 to \$1.75 per thousand. If they are simply dipped into the creosote the cost will be about \$0.60 to \$1.50 per thousand; if brush-treated with two coats after the roof is laid, about \$0.40 to \$0.90 per 100 square feet. Shingle stains which cost from about \$0.40 to \$1 per gallon make, of course, a more expensive treatment, the cost of dipping per thousand being about \$1.50 to \$3.50, and for simply brush-treating after the roof is laid about \$0.60 to \$1.50 per 100 square feet.

# CHAPTER XV

## PROLONGING THE LIFE OF LUMBER AND LOGS

**Methods of Treating Lumber for Rough ·Construction.**—An immense quantity of structural timber is used annually in the United States under conditions which subject it to decay. Unfortunately, only a small percentage is treated, so that our depreciation losses are both rapid and large. Of course, wherever the timber can be protected from the weather, or warm damp atmosphere, no artificial treatment is necessary, as it willu nder such conditions last indefinitely. However, in bridges, trestles, piers, walks, platforms, docks, etc., etc., where such timbers are used, failure from decay is all too common. (See Plate XXI, Fig. D.) This is particularly true.if the wood comes in contact with the soil. While it is not possible to lay down a set of instructions which will cover all cases, certain general rules should, however, prove of direct value to those using this class of material.

Whenever possible, all such timbers shonld be kept from contact with the ground. In many cases, they can be placed on concrete or stone piers, and by this simple treatment, their life considerably prolonged.

The most effective treatment which can be given such timbers is to impregnate them with coal-tar creosote. For severe cases, the full-cell process should be used; for less severe, the empty-cell or Card. From 5 to 12 pounds of oil should be injected, depending upon local conditions. As sapwood is just as strong as heartwood, the treatment of this kind often enables the use of sappy timbers, which, untreated, would not be used. Hence, specifications for the raw material can be made more lenient and the timber can frequently be secured at a lower initial price. All structural timbers injected with preservatives should be framed as close to final dimensions before treatment as possible.

Next to impregnation tieatments, brush treatments with·a high-grade coal-tar creosote are recommended. If these are

used, the wood should first be thoroughly air seasoned and dry at the time the preservative is applied, otherwise little or no beneficial results will be secured. Two coats are better than one, and in all cases the oil should preferably be brushed on hot (about 150° to 175° F.), care being taken to soak especially all joints, bolt holes, and laps.

In timbers which decay only at the joints, the joints only need be coated with hot creosote, the rest of the member being left untreated. All joints made in timber which has been impregnated should always be brush-coated with hot creosote if these are framed after treatment.

Timbers treated with creosote cannot as a rule be painted, as the paint will not adhere to them. They will, however, be turned a deep brown which, on prolonged exposure, will become lighter in color. For rough construction, the oil will take the place of paint, and in this connection also effect a saving.

**Methods of Treating Lumber for Buildings, Greenhouses, and Cars.**—In general lumber used in buildings, cars, etc., cannot be creosoted because it is desirable to paint it, and as mentioned, paint does not readily adhere to creosoted wood. In certain cases, however, this is not necessary. For example, sills in buildings, beams in porches, etc., where the wood is covered, can be profitably treated. Thus the sills and beams used in constructing the so-called "Sanitary floors" in the South, particularly New Orleans, are impregnated with 10 to 12 pounds of creosote per cubic foot, and very good results obtained. Even in silos, if it is not desired to paint them, creosoted lumber can be used to advantage provided it is permitted to air season before the silos are filled.

When the wood is to be painted, a treatment with one of the antiseptic salts is recommended. Zinc chloride, mercuric chloride copper sulphate, or sodium fluoride will all give good results. As mercuric chloride and copper sulphate cannot be used in steel cylinders, it is necessary to soak the lumber in stone, concrete, or wooden vats containing these preservatives. This is done as described under the Kyanizing process. These salts have a further disadvantage in that they will attack the steel in carpenters' tools. Zinc chloride and sodium fluoride can be handled as described in the Burnett process. The lumber should then be air seasoned before it is placed in the building, after which it can be handled like untreated lumber. Paint of all colors

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will in general adhere readily to wood treated with the salts just mentioned, and will aid materially in holding them in the wood. Treatments of this kind are recommended particularly for such places as floors and columns in porches, trim around the eaves, bench boards and sills in greenhouses, roofs in dye houses, and in fact, all places where the wood is subject to decay, and where it is necessary to pain it with light colored pigments. Much has been written of "dry rot" in buildings. This can be greatly retarded or prevented by the treatments described, since it is caused by a fungus. In all cases, the lumber should be framed to as near the exact dimension it is to have as can be done because any subsequent cutting will expose the untreated interior and hence shorten the life of the wood. It is believed that there is a good field for many lumber companies to operate treating plants for preserving wood used in building construction. By so doing, woods which are not naturally durable could be made to compete with the more expensive and naturally durable woods like cypress, cedar and redwood, and would in certain cases be preferable in that some of them possess greater strength. Treatments with the above salts will also resist insect attack.

The life of untreated wood can be prolonged in many cases by keeping a circulation of dry air about it. Stagnant air in cellars or store rooms is particularly liable to start decay, and it frequently happens that by simply improving the ventilation, further decay can be arrested. Of course, when untreated wood is used, sapwood is a detriment and "all heart" pieces are always to be preferred. In certain types of flooring, creosoted planks can first be laid and then faced with thinner planks of untreated wood. If timber is set subject to decay, ordinary paint will seldom arrest the decay unless all surfaces of the wood are treated. In fact, the paint may actually hasten decay in some instances, as for example, when only one or two surfaces are painted and the others are left unpainted. The unpainted surfaces will absorb moisture, while the painted surfaces will retard it from evaporating, and thus the wood will actually have more moisture in it and in such a condition be more susceptible to decay. This is a common occurrence in the floors of outdoor porches, the upper side of which is usually the only surface painted.

It has been reported that dry rot in factories can be checked by raising the temperature in the rooms to 120° F. or more for a

few hours. The author is unable to verify these reports but believes the treatment well worthy of trial by those troubled with this form of decay.

**Methods of Preserving Logs from Decay.**—It is very difficult to store logs with bark on them for any length of time without their being attacked by decay. This is particularly true of logs having much sapwood, like the gums, sycamore, maples, birch, etc. Decay can be retarded if the ends of these logs are given one or two coats of creosote as soon as possible after they are cut. The same should be done wherever the bark has been broken off. If it is simply desired to retard checking, the ends of the logs should be coated with paint, or better still, hot paraffin. In this way the logs can be protected at a cost of only a few cents per thousand feet of lumber. To protect logs from insect attack, it is necessary to peel them or soak them in water. In special cases, the methods described below might be used.

**Methods of Treating Log Cabins and Rustic Furniture.**—No satisfactory method of keeping bark on wood for any appreciable length of time is known, particularly if the bark is soaked by rain from time to time. Fungus and insects are both very apt to work in under the bark and cause it to fall off.

Damage of this kind can be largely prevented by cutting the logs in late autumn and piling them so that they will dry as rapidly as possible or by utilizing them immediately. Even better, but more expensive and troublesome results can be obtained by cutting the logs in the spring and stripping them in laps of bark, which at this season peels readily. The bark can then be soaked in a 1 percent solution of mercuric chloride and the logs used directly. After the logs have air-dried, they can be brush treated with one or two coats of coal-tar creosote or carbolineum. When this has dried for several days, the bark can then be nailed to the logs. Treatments of this kind are the most effective known. Care should be taken in handling the mercuric chloride solution as this is extremely poisonous, and also in thoroughly air-seasoning the treated logs so that the odor of oil will not prove objectionable.

Rustic furniture should be kept under cover and dry. Little or no trouble will then be experienced with decay. Insects; however, may attack it, as is evidenced by little mounds of sawdust and miniature pin holes in the bark. Sponging such furniture thoroughly with kerosene or benzene will usually

kill the insects and stop their depredations. Or if the holes are caused by larger wood-boring insects, carbon bisulphide can be injected into the holes, which should then be immediately stuffed with putty, or a similar substance. The offensive odor of the bisulphide will leave the wood in a few days.

# CHAPTER XVI

## THE PROTECTION OF TIMBER FROM FIRE

The use of wood as a construction material, especially in congested centers as in cities, has a serious objection due to the comparative ease with which it can be ignited and with which it burns. The objection to its use because of this property is rapidly growing and will undoubtedly continue to do so. The fire losses in the United States are enormous, reaching the vast sum of $215,000,000 per year. Of course, all of this is not due to the use of structural wood, as the contents of even "fireproof" buildings are inflammable and are frequently destroyed. A few cities have already passed ordinances prohibiting the use of natural wood in buildings over a certain number of stories in height, and other cities have specified against the use of wooden shingles within their more congested limits. Such action has attracted keen attention of late to the possibility of rendering wood noncombustible. This problem is quite different from the problem of protecting wood from decay and has to do almost entirely with the control of the gases driven off from wood when heat is applied to it. If these gases can be diluted with a noncombustible gas in proper proportions, the wood will charr and not burn. On the other hand, if these gases can be kept from mixing with requisite amounts of oxygen, a similar result can be secured. In either event, the original properties of the wood will be destroyed, so that, strictly speaking, it is practically impossible, if not impossible, to render wood "fireproof." The best that can be expected is to either make the wood noncombustible or slow burning. The temperature at which natural wood will ignite under ordinary conditions is about 500° F. The temperature of a burning building is estimated at about 1700° F. The ease with which natural wood ignites, therefore, when subjected to such high temperatures, is readily seen. As great progress in protecting wood from fire has not been made thus far as in protecting it from decay, and but two companies are now in operation in this country. Progress has been considerably

retarded by fraudulent practices on the part of defunct companies claiming to "fireproof" wood, and by contractors who claimed to use such wood in their construction. Furthermore, a gross misunderstanding exists concerning the possibilities of rendering wood noncombustible, which has often led to the drafting of impracticable specifications. Much work remains to be done in perfecting present methods and in enlightening the public to what can reasonably be expected.

The chief objections raised against the use of "fireproofed" wood aside from increased cost are the leachability of the chemicals, their corrosive action on metals, their effect on the strength of the wood, and their action on paints and varnishes. Wood impregnated with the best known fire retardent chemicals cannot be set in wet or damp situations or exposed to the weather, as the chemicals will be leached from the wood. Nails, hinges, etc., in contact with such fireproofed wood will, when it becomes damp, be corroded. Wood treated with these chemicals is rendered more brittle than wood not treated, although the loss in strength can be greatly decreased by proper methods of treating and drying. For many purposes, as in trim in buildings, the question of decreased strength should have little or no serious consideration, as this property is not important. Due to their hygroscopic nature, the salts are quite liable to keep the wood moist and hence interfere with the adhesion of paint or varnish.

When not exposed to the weather or unusual dampness, "fireproofed wood," as it is now known, has given very satisfactory service. It retains its resistance to fire for long periods, and, so far as its other properties are concerned, behaves in much the same manner as untreated wood.

*The Theory of Rendering Wood Fire Retardent.*—Those results which have been most successful thus far have been founded on one or more of the following theories:

1. To cover the wood with a chemical which, like sodium silicate, when heated will fuse over the surface and prevent a free access of oxygen to the wood.

2. To cover the wood with a noncombustible material which, like asbestos or metal, will prevent a free access of oxygen to the wood and thus produce a slow distillation.

3. To impregnate the wood with a chemical which, like borax, when heated will liberate water vapor or steam, thus diluting the combustible gases so that their ignition cannot occur.

4. To impregnate the wood with a chemical which, like salts of ammonia, when heated will liberate a noncombustible gas, thus diluting or combining with the combustible gases so that combustion is impossible.

Owing to their manner of application, these various theories can be classified into two groups of treatment which may be called superficial and impregnation processes.

**Superficial Processes.**—These consist in protecting the surface of the wood from contact with flames. If the protective coating is a liquid like sodium silicate, it is simply painted onto the wood or the wood is dipped into it. Such treatments, while effective in retarding the ease with which the wood will catch on fire, are not conducive to best results. Other superficial processes consist in covering the exposed surface of the wood with a noncombustible material such as asbestos or metal. Unless the covering entirely surrounds the wood, the temperature of the protected face may become so high as to cause the wood to ignite. When, however, the covering entirely surrounds the wood the protection is very efficient as burning is almost entirely excluded and only charring is produced. As might be surmised from its manner of application, this method of treatment has only a limited use and is quite costly.

**Impregnation Processes.**—These are conducted at the present time in much the same manner as the Bethell or Burnett processes (see description) of protecting timber from decay. They differ from them in two respects: (1) different chemicals are used, and (2) the wood is generally kiln-dried after the chemicals have been forced into it, in order to remove the large amount of water injected into it. As a general rule, only thoroughly air-seasoned wood is treated, this usually in the form of rough sawn lumber. The kiln drying of "fireproofed" timber requires a nice adjustment in that the temperatures used must not be so high as to volatilize the chemicals injected or cause them to "pull" toward the surface. Checking and warping must also be guarded against. Any efficient kiln-drying process can, however, be employed provided it is properly applied.

**Chemicals Used.**—A large variety of chemicals hve been tested by various experimenters in the attempt to render wood noncombustible. The more important of these chemicals thus tried, either alone or in combination, are: Ammonium sulphate, phosphate and chloride, zinc sulphate and chloride, borax,

cresylates of mercury, lead, copper, iron, and zinc, sulphate of iron, alum, calcium bisulphite and lime, sodium silicate, oxalic acid, potassium and sodium carbonate. Best results have been secured with the salts of ammonia, borax, and sodium silicate.

"Fireproofing" tests have been made at the U. S. Forest Products laboratory on noble fir, using the following fire-retarding agents.[1]

| Strength of solution | Amount dry salt injected per cubic foot of wood |
|---|---|
| 33 percent solution sodium carbonate | 11 pounds |
| 35 percent solution sodium bicarbonate | 11 pounds |
| 30 percent solution oxalic acid | 10 pounds |
| 20 percent solution borax | 5 pounds |
| 20 percent solution ammonium chloride | 5½ pounds |

## CHEMICAL FIRE RETARDENTS

**Sodium Carbonate.**—Sodium carbonate did not prove efficient in retarding combustion (Fig. 24). It also caused a marked weakening of the wood.

**Sodium Bicarbonate.**—Sodium bicarbonate did not prove efficient in retarding combustion (Fig. 24), and also caused a marked weakening of the wood.

**Oxalic Acid.**—Oxalic acid did not prove efficient in retarding combustion (Fig. 24), and also caused a marked weakening of the wood.

**Borax.**—Borax was of considerable value in retarding combustion (Fig. 24). The dotted curve (G), Fig. 24, shows the comparison with natural wood and the other fireproofing agents used. The points determining the position of this curve were obtained after the piece had become charred and incandescent. A small amount of an inflammable gas, probably carbon monoxide was generated, which burned with a small blue flame on the top of the test specimen, but only with the aid of the pilot light.

**Ammonium Chloride.**—Ammonium chloride proved of considerable value in retarding combustion (Fig. 24). The points determining the position of the dotted curve (F), Fig. 24, represent the same condition as was described under borax. How-

[1] From Proceedings American Wood Preservers' Association, 1914, by Robert E. Prince.

ever, ammonium chloride is somewhat hygroscopic and its use may be restricted for this reason.

**Commercial Treatment.**—A number of tests were made on pieces of red oak, treated by a commercial fireproofing company with a solution containing ammonium phosphate and ammonium sulphate. The strength of the solution was not known. Ammonium phosphate and sulphate proved of considerable value in retarding combustion.

**Tests to Determine the Inflammability of Timber.**—Several methods of testing the inflammability of wood have been sug-

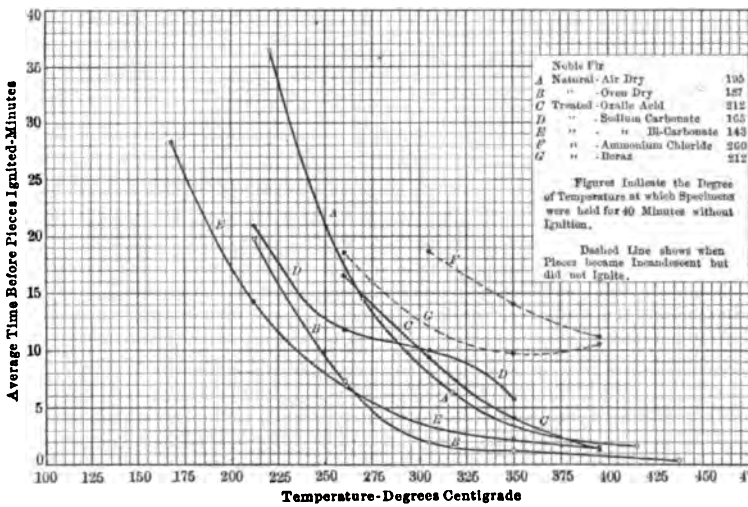



FIG. 24.—Time required to ignite natural wood and wood impregnated with fire retardent chemicals when subjected to various temperatures.

gested. The more common of these are the shaving test, crib test, spot test, and electric furnace.

**Shaving Test.**—Shavings planed from the treated wood are placed in a wire basket over a Bunsen burner. Notes are taken on the length of time required to ignite the shavings, the character of the burning, the length of glow, and the loss in weight due to the burning or smoldering. This method of test is faulty in that the wood is so finely divided that the volatile gases are readily driven from it and conditions comparable to practice are not duplicated. Furthermore, it is difficult to get concordant results due to varying air currents and temperatures.

**Crib Test.**—So called because small splints of wood about

$1/2 \times 1/2 \times 4$ inches are cut from the treated wood and piled in a crib over a Bunsen burner, the flame being permitted to pass through them. While better than the shaving test, the method is also open to similar criticism.

**Spot Test.**—A flame (usually of illuminating gas)[1] is played over the surface of a treated piece of wood. The depth to which it charrs or burns and the character of burning or glow are noted. The temperature of the flame may be read from a pyrometer, the thermocouple of which is placed against the wood at point of test. This method is much more comparable to practice and gives good indicative results, which, however, are faulty in that they are difficult of duplication.

**Electric Furnace.**—This method of test gives concordant results when small pieces of wood are treated, and enables an accurate comparison between various treatments. It is objectionable, however, in that the heat is applied to all sides of the test specimen and usually requires that the treated plank be cut into small sizes. For laboratory work, however, this method of testing has been found very satisfactory. The apparatus consists of a silica tube, wrapped with nichrome ribbon. An iron tube fitted with a mica sight is cemented below the silica tube.

The specimen of wood, after being lowered into the silica tube, is heated at a uniform rate, by passing 24 amperes of electric current through the nichrome ribbon. Temperature readings are obtained from a thermocouple placed beside the specimen and reading direct from a Hoskins pyrometer. A pilot light is used to ignite the gases distilled from the wood. Compressed air partially dehydrated by expansion is passed through the apparatus, its intensity being indicated by a sensitive liquid manometer. The temperature of ignition, character of combustion or glow, and loss in weight due to the burning for a 3-minute period is noted. After ignition the specimen is lowered into the iron tube, where it can burn of its own heat.

**Cost of Rendering Wood Noncombustible.**—The cost of rendering wood noncombustible is in general higher than to protect it from decay. As has been mentioned, most effective results in fireproofing wood have been secured by injecting chemicals into it. These are more corrosive than the common preservatives and hence increase plant depreciation. Then, the preservatives them-

[1] A plate heated electrically has been suggested in place of the flame as being easier of control.

selves are comparatively expensive. Finally, the wood, after it has been treated, must generally be kiln-dried to avoid loss in time and checking in seasoning. Taking the above factors into consideration, the cost of rendering wood fire retardent is approximately as follows, when chemicals like ammonium phosphate, costing about 8.5 cents, and ammonium sulphate, costing about 3 cents per pound, are used.

ESTIMATED COST OF RENDERING WOOD NONCOMBUSTIBLE PER M.B.M.

| | |
|---|---|
| Cost of handling | \$2.00– \$3.00 |
| Plant depreciation and maintenance | 0.90– 2.00 |
| Chemicals | 10.00– 18.00 |
| Kiln-drying | 2.00– 4.00 |
| Total | \$14.90–\$27.00 |

The lower figure of \$14.90 per thousand assumes the plant in continuous operation and the consumption of chemicals about 175 pounds per M.B.M. The upper figure of \$27 covers operations which are not continuous and allows for a heavier injection of the salts into the wood.

**The Effect of Zinc Chloride and Creosote on the Inflammability of Wood.**—Although zinc chloride is not one of the most efficient fire retarding chemicals, nevertheless wood treated with it is much more difficult to burn than untreated wood. This makes zinc-chloride treated timber of particular value in those locations where decay is rapid and danger from fire important, as for example in coal mines. Timber treated with zinc chloride will ordinarily ignite at the same or lower temperatures as untreated wood but will burn far more slowly. This is due in a large measure to the hygroscopic nature of the salt. Some tests made in the electric furnace above described at the U. S. Forest Products Laboratory on zinc-chloride treated hemlock gave a temperature of ignition of 287° C. as against 320° C. for untreated wood. Only 19 percent of the treated wood was destroyed, however, as against 29 percent of natural wood.

Much discussion has occurred concerning the inflammability of wood treated with coal-tar creosote. This matter was also investigated at the U. S. Forest Products Laboratory and it was found that wood freshly treated with creosote was very inflammable, but that its resistance to burning increased with its age. This is undoubtedly due to the lighter oils volatilizing from the

wood and leaving the heavier oils. When tested under the conditions analogous to the zinc-treated specimens mentioned above, freshly creosoted hemlock ignited at a temperature of 173° C. and lost 40 percent of its weight in a 3-minute burning period. When allowed to air-season for 90 days, the temperature of ignition rose to 216° C. and a loss of only 27 percent in weight occurred. Many instances showing the resistance of seasoned creosoted timber to fire have been reported, of which the following are cited:

After the Jacksonville fire the creosoted telephone poles were standing in good condition although the buildings all about them had been destroyed.

The Stuyversant docks at the same place were built of untreated and creosoted timber. The latter was easily extinguished while the former was completely destroyed.

In Baltimore the creosoted wood-block streets did not burn but came through the fire better than pavements of asphalt which melted and ran down the sewers.

The author saw a shaft of a coal mine in Pennsylvania which had caught fire, it being timbered with untreated and creosoted props. After the fire was extinguished by smothering the mouth of the shaft, all the untreated props had been burned to such an extent as to be useless while those creosoted were simply charred and not replaced.

It appears that the creosote in timber when it does ignite burns for a long time in much the same manner as oil does in a wick; hence the reason why the wood itself is so slightly consumed. It must not be construed that creosoted timber is fire resistant in the same sense that zinc-treated timber is, but that when thoroughly air seasoned it burns for some time with less damage to the wood than untreated wood.

## CHAPTER XVII

## THE PROTECTION OF WOOD FROM MINOR DESTRUCTIVE AGENTS

A description of the manner in which these minor destructive agents attack wood has been given in Chapter II. We will now consider methods of protection.

**Alkaline Soils.**—While it is well known that certain alkalies will attack wood and eventually disintegrate it, there is no positive evidence which shows that their presence in the so-called "alkali soils" does this. It is quite likely that the alkali is not sufficiently concentrated or heated to sufficient temperature to cause disintegration. In all cases which have been examined by the author, such as deteriorated wood from flume pipes, cross-ties or poles, fungus was always present. It is believed, therefore, that if the growth of the fungus is prohibited, the deterioration can be materially reduced or eliminated. In other words, the wood should be treated for decay, the process to be selected depending upon local conditions as already described. By so doing it is quite likely that the effect of the alkali in the coils can be generally disregarded.

**Birds.**—The destruction of structural timber by birds is so small as to warrant little comment, and certainly does not justify killing them. Woodpeckers will at times drill holes into buildings and poles, and the size of the holes and the oddity of the attack has given rise to an exaggerated idea of the destruction done. When buildings are attacked, they are generally more or less deserted and usually good for nothing but birds' nests at best.

The so-called destruction in poles is apparent rather than real, as has been shown in Chapter II, although at times the holes drilled by the birds may cause a real damage. No good method of preventing such attacks is known. Creosoting the poles under pressure is of assistance, although the birds will at times attack creosoted poles. Plugging the holes is of no value as the birds will drill new holes. It often appears to be a matter of "life or death," and considering the great good and little real damage that they do, destruction caused by birds had best be charged as an

operating expense and borne with a smile. Nesting boxes can often be used with great satisfaction, if hung on posts, poles or buildings, and thus prevent damage (see Plate XXIII Fig. C). The use of such boxes has been extensively tested in the Grand Duchy of Hesse, where in 2 years all the boxes were inhabited.

**Sap Stain.**—To be efficient, all known methods of protecting wood from sap stain must be applied before the stain enters the wood . If the logs are stained before they are cut into lumber, no satisfactory process is known for removing the stain. Logs should therefore be cut as soon as possible after they are felled, particularly during warm weather.

The most effective means of preventing stain is to kiln dry the lumber immediately after it has been sawed, and then keep it under cover. In this manner, stain can be entirely prevented. This method, however, is generally too expensive and cumbersome for all but the best grades of lumber.

For rough lumber, dipping in a solution of bicarbonate of soda gives best commercial results. In practice, this is done by having the freshly cut boards carried through a tank of the soda solution on their way to the sorting table. In this manner no extra expense for handling is required. A 5 to 8 percent solution is usually sufficiently strong. This should be kept warm by means of a steam coil in the bottom of the tank, which can be constructed of wood, iron or concrete. A few companies are now maufacturing "soda-dipping" tanks and will furnish a complete outfit (see Plate XXII, Fig. A) or the tanks can be constructed by an ordinary mechanic. After the lumber has been dipped in this manner, it should be piled with open air courses so that it will dry rapidly.

An extended series of tests were made by the United States Forest Service in co-operation with the Great Southern Lumber Company at Bogalusa, La., in which pine boards were dipped in a variety of solutions. It was found that solutions of mercuric chloride, varying in strength from about 0.2 to 0.3 percent, were most effective in preventing stain, but on account of their very poisonous nature, cannot be generally recommended.

The following conclusions are drawn from these tests:[1]

1. Freshly cut sap lumber when stacked in the yard to dry should be stacked in open piles to permit a free circulation of air. Boards so piled season in about half the time required for those

[1] Circular 192 United States Forest Service.

piled in close piles. Open piles, moreover, are not so severely attacked by insects and are more effectively protected against sap stain.

2. In commercial work sap stain can be most effectively prevented by dipping boards in solutions of sodium bicarbonate. Such solutions, though they give fairly good results, leave much to be desired. The strength of the solution should be determined by the severity of the conditions under which the boards are to season, but in general it will require from 5 to 10 percent. Care should be taken that the chemical used is not mixed with adulterants.

3. The best results in preventing sap stain were secured with mercuric chloride solutions, but on account of their poisonous nature they are not recommended for general use.

4. The solution made by mixing sodium carbonate and lime was not as effective as one of sodium bicarbonate alone. Moreover, it had a greater tendency to streak the surface of the boards with a white precipitate.

5. Solutions of magnesium chloride, calcium chloride, sodium hydroxide, phenol, copper sulphate, and zinc chloride did not prevent sap stain; nor did sprinkling the boards with naphthalene flakes give satisfactory results.

6. On account of cheapness and facility in operation, it is recommended that sap-stain solutions be applied to the boards by machinery. If this is done, the cost of treating lumber with solutions of sodium bicarbonate will amount to from about 7 to 10 cents per 1000 board feet.

7. The indications are that shavings planed from soda-dipped boards do not burn as readily as those from untreated boards, but the difference in inflammability is so slight that for commercial purposes it may be neglected.

**Sand Storms.**—The destruction of timber in the United States by sand storms is insignificant. Far more is destroyed by wind and sleet storms against which there is, of course, no known method of protection except heavier and more expensive construction. In certain portions of the Southwest the wind carrying sand at high velocity so wears away poles, stakes and posts that renewal is sometimes necessary. (See Plate XXII, Fig. B.) About the only practical method known of retarding such damage is to nail planks of wood or sheets of metal to the poles and posts and after these have been destroyed, replacing them.

## CHAPTER XVIII

## THE STRENGTH AND ELECTROLYSIS OF TREATED TIMBER

**The Effect of Air Seasoning on the Strength of Wood.**—It has been stated in Chapter IV that a considerable amount of water can be removed from green wood, without affecting its strength. As soon, however, as the water begins to leave the cell walls so that their moisture content is decreased, the strength of the wood rapidly increases. This is shown in Fig. 109 where the strength of wood is plotted against the amount of water it contains. Prolonged air seasoning removes a certain amount of water from the cell walls and hence increases the strength of wood. The amount of water thus removed depends upon the temperature and humidity of the surrounding air and the size and kind of wood being seasoned. For example, it is greatest in warm dry air (as in summer) and in thin boards (1 inch or less in thickness). Material of this kind is called "air dry or seasoned" when it contains about 8 to 12 percent of water. If dried to lower moisture than this it is very probable that the wood will re-absorb moisture. Air-dry lumber containing 8 to 12 percent of moisture is therefore seasoned about 16 to 20 percent below its fiber-saturation point and has about twice the strength of green wood. On the other hand if the boards are larger, say 6 to 10 inches in thickness it is very likely their "air-dry" moisture will be 15 to 20 percent rather than 8 to 12 percent. Consequently their strength will not be increased to the same degree. It is evident, therefore, that the term "air dry" is a very variable and arbitrary one. If now, the wood is dried in a kiln and its moisture reduced to say 2 to 3 percent, its strength will be increased considerably over what it was in an air-dry condition. Thus, other things being equal, the more moisture there is removed from wood, the greater will be its strength (Fig. 25). This relation has been equated by Tiemann[1] for longleaf pine with the following formula:

[1] Bulletin 70, United States Forest Service.

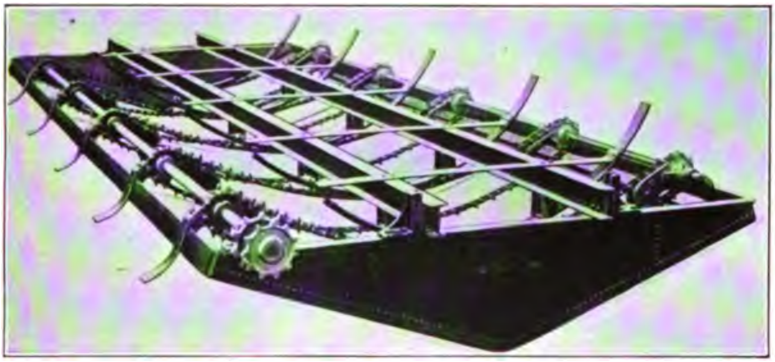


FIG. A.—Type of soda dipping tank manufactured by the Lufkin Foundry and Machine Co.

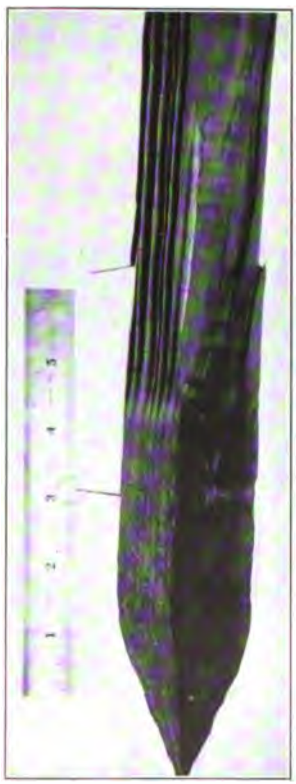


FIG. B.—Stake damaged by sand storms in southern California. Compare portion in the ground with portion above ground. (Photo courtesy of the Am. Tel. & Tel. Co.)

(Facing page 224.)

PLATE XXII

FIG. C.—Section of an experimental track laid with steel ties. (Photo courtesy of the Ry. Eng. Ass'n.)

FIG. D.—A fence of concrete posts, Madison, Wis. (Photo courtesy National Concrete Machinery Co.)

$$C = G\,(22.1\,P^2 - 1335\,P + 25{,}610)$$

where $C$ = crushing strength in pounds per square inch

$G$ = specific gravity of dry wood

$P$ = percent of moisture.

On account of the wide variability in the structure of wood, the equation is applicable only within certain limits, and will not, of course, give the exact strength for each and every piece of wood, but is sufficiently close for most commercial engineering problems.

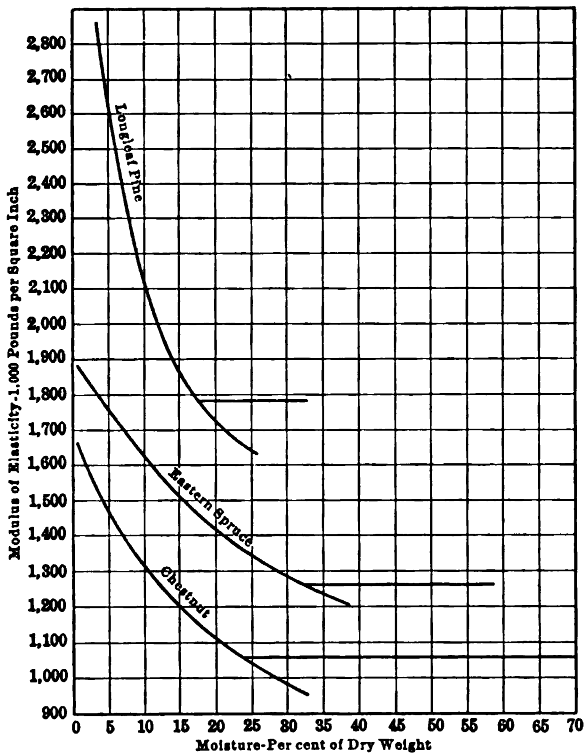



FIG. 25.—Moisture-strength curves for longleaf pine, eastern spruce and chestnut. Note fiber-saturation points.

Lowering the moisture content of wood below its fiber-saturation point produces certain phenomena; the more important, so far as strength is concerned, being shrinkage and cell slitting. Both of these vary with the kind of wood, the degree to which it is seasoned, and the manner in which it is seasoned. Conifers shrink less than hardwoods, and the drier the wood the greater

the shrinkage. Given the specific gravity of a piece of wood its shrinkage from a green to oven-dry condition can be fairly closely approximated from the following logarithmic equations developed by J. A. Newlin:

Shrinkage in volume percent $= 26.5\,G^{1.00}$
Radial shrinkage in percent $= 9.5\,G^{1.00}$
Tangential shrinkage in percent $= 16.5\,G^{1.00}$
where $G$ = specific gravity.

When water leaves the cell walls it sometimes happens that these check open and become more or less filled with microscopic slits (Fig. 24). These slits apparently weaken the wood but their weakening effect by no means offsets the marked increase in the strength of the wood due to its loss of water. If wood which has once been thoroughly air-dried is resoaked in water until it contains as much water as it originally had, its strength will be found to be less than the original green strength. The slitting of the walls probably has much to do with this.

From the above discussion, it can readily be seen that any treating process which tends to keep wood dry will, provided it does not in itself weaken the wood, tend to increase the strength of the wood. Thus treatments with creosote tend to retard the absorption of water and hence keep the wood in a stronger and more resilient condition than untreated wood or wood treated with a preservative like zinc chloride. This is of decided advantage in certain cases, as in paving blocks, and is undoubtedly one reason why creosoted blocks have resisted wear so much better than similar blocks laid untreated. On the other hand, objections have been raised to the seasoning of wood, particularly in mines, where certain operators assert that they prefer green wood to dry or partially dry as it bends more and gives better warning of danger from rock fall.

**The Effect of Steaming on the Strength of Wood.**—Little is known concerning the effect of superheated steam on the strength of wood, but from our knowledge of the effect of temperature on wood, the rapid drying of wood and practical operative results with superheated steam, it appears that it is very prone to seriously weaken wood and render it brash and brittle.

Saturated steam is in common use in preparing wood for treatment as has been shown in previous chapters. Saturated steam in itself does not dry wood, but heats it so that drying is possible. In fact, while the wood is in the steam it may actually take up

water, particularly if it is already partially seasoned. This is shown in the following table:

TABLE 34.—INCREASE IN WEIGHT OF LOBLOLLY-PINE TIES DUE TO STEAMING[1]

| Conditions of steaming | | Gain in weight per tie, due to steaming | |
|---|---|---|---|
| Period | Pressure per square inch | Green ties | Air-seasoned ties |
| Hours | Pounds | Pounds | Pounds |
| 4 | 10 | 2.13 | 5.1 |
| 4 | 20 | ............... | 6.9 |
| 4 | 30 | 0.62 | 6.3 |
| 4 | 40 | 1.12 | 8.1 |
| 4 | 50 | 0.62 | 4.3 |
| 6 | 20 | ............... | 10.8 |
| 10 | 20 | 1.00 | 10.7 |

After the wood has been heated and the steam around it removed, the heat units stored in the wood will evaporate much of the water it contains and produce a condition of partial dryness or "seasoning." A vacuum applied immediately after the steam bath will further increase the drying, since it lowers the temperature at which the water will vaporize. Common practice, therefore, is to steam the wood and then apply a vacuum. The important items to consider, in so far as the effect of steaming on the strength of wood is concerned, are the temperature of the steam and the length of time it is applied to the wood. The best data on this subject known to the author is contained in United States Forest Service circular 39, which summarizes the results of about 6000 tests. Due to the variability of the wood used and the complexity of the problems, it is probable that further tests might change some of the conclusions there drawn, but the essential features are probably correct. In general, it appears from these tests that steaming at high temperatures, or lower temperatures for long periods, materially weakens the strength of wood. The extent of the weakening will depend upon the kind of wood, its moisture content at the time of seasoning, the character of the wood structure such as density, rate of growth, etc., and the manner in which the steam is applied. Disregarding the individual effect of each of these, and lumping them all together, the effect of the temperature of the steam and the length of time it is applied is shown in Table 35.[2]

[1] Circular 39, United States Forest Service.
[2] United States Forest Service Circular 39.

TABLE 35.—EFFECT OF STEAMING ON THE STRENGTH OF GREEN LOBLOLLY PINE

(Specimens, 2 by 2 inches; tested immediately after treatment)

| Treatment | Cylinder conditions | | | Strength (untreated wood = 100 percent) | | | | Rings per inch[1] | | Moisture[1] | | Specific gravity (dry)[1] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Steaming | | | Static | | Impact | | | | | | | |
| | Period | Pressure per square inch | Temperature | Bending, modulus of rupture | Compression parallel to grain | Bending, height of drop causing complete failure | Average of the three strengths | Control | Treated | Control | Treated | Control | Treated |
| | Hr. | Lb. | °F. | P.ct. | P.ct. | P.ct. | P.ct. | | | P.ct. | P.ct. | | |
| Steam, at various pressures | 4 | ........ | 230[2] | 91.3 | 79.1 | 96.4 | 88.9 | 7.0 | 7.5 | 60.8 | 49.2 | 0.490 | 0.500 |
| | 4 | 10 | 238 | 78.2 | 93.7 | 93.3 | 88.4 | 6.0 | 5.0 | 52.2 | 37.6 | 0.489 | 0.468 |
| | 4 | 20 | 253 | 83.3 | 84.2 | 91.4 | 86.3 | 7.0 | 8.0 | 32.6 | 34.3 | 0.518 | 0.513 |
| | 4 | 30 | 269 | 80.4 | 78.4 | 89.8 | 82.9 | 7.0 | 6.5 | 39.8 | 48.1 | 0.493 | 0.479 |
| | 4 | 40 | 283 | 78.1 | 74.4 | 74.0 | 75.5 | 7.0 | 7.0 | 40.5 | 42.5 | 0.519 | 0.509 |
| | 4 | 50 | 292 | 75.8 | 71.5 | 63.9 | 70.4 | 7.0 | 7.0 | 41.8 | 46.2 | 0.531 | 0.508 |
| | 4 | 100 | 337 | 41.4 | 65.0 | 55.2 | 53.9 | 6.5 | 7.0 | 52.3 | 45.5 | 0.501 | 0.456 |
| Steam, for various periods | 1 | 20 | 257 | 100.6 | 98.6 | 86.7 | 95.3 | 6.0 | 6.5 | 31.7 | 39.1 | 0.484 | 0.489 |
| | 2 | 20 | 267 | 88.4 | 93.0 | 107.0 | 96.1 | 5.5 | 5.0 | 54.5 | 55.9 | 0.474 | 0.490 |
| | 3 | 20 | 260 | 90.0 | 93.6 | 84.1 | 89.2 | 7.0 | 6.0 | 37.1 | 33.8 | 0.532 | 0.531 |
| | 4 | 20 | 253 | 83.3 | 84.2 | 91.4 | 86.3 | 7.0 | 8.0 | 32.6 | 34.3 | 0.518 | 0.513 |
| | 5 | 20 | 253 | 85.0 | 78.1 | 84.2 | 82.4 | 6.0 | 6.5 | 38.2 | 39.3 | 0.506 | 0.509 |
| | 6 | 20 | 242 | 95.2 | 89.8 | 76.0 | 87.0 | 5.0 | 6.0 | 58.9 | 36.5 | 0.453 | 0.505 |
| | 10 | 20 | 255 | 73.7 | 82.0 | 76.0 | 77.2 | 6.0 | 7.0 | 48.0 | 47.9 | 0.523 | 0.516 |
| | 20 | 20 | 258 | 67.5 | 65.0 | 99.0 | 77.2 | 7.0 | 7.0 | 61.9 | 52.8 | 0.523 | 0.508 |

[1] Obtained from specimens used in static bending tests.

[2] It will be noted that the temperature was 230°. This is the maximum temperature by the maximum-temperature recording thermometer, and is due to the handling of the exhaust valve. The average temperature was that of exhaust steam.

In this table the word "control" refers to the test pieces cut from the ends of the ties which were left untreated in order to furnish a standard of comparison. It should be noted that these pieces were tested immediately after treatment. It was found that if they were air seasoned after treatment and then tested they regained a large part of their original strength. Sufficient reliable data is not available to state accurately what is the maximum temperature of steaming or maximum duration of steaming that should be used. The conclusion drawn from the tests just quoted was that "for loblolly pine the limit of safety is certainly 30 pounds for 4 hours, or 20 pounds for 6 hours." It is well known that some of the best results secured in the treatment of wood in this country have been obtained from timbers (longleaf pine piling) which were steamed at higher temperatures and longer periods than this, hence it is entirely probable, when full information is available, that more severe steaming treatments will be found safe and practicable.

**The Effect of Boiling Wood in Creosote upon its Strength.**—If wood is submerged in creosote which is heated above the boiling point of water under atmospheric pressure only, the water contained in the wood will be converted into steam. Unless confined, the steam will escape and thus the water content of the wood will be reduced. It is obvious, therefore, that boiling wood in creosote seasons the wood and is quite a different action from steaming wood, which as already described, is simply a means of heating it. If, however, the wood is heated in oil under pressure, the action should be similar to that produced by steaming it, since the pressure will prevent the water from vaporizing.

It is well known that rapidly seasoning timber is very apt to weaken it, because it tends to develop checks and slits. This is particularly true of woods having a complex structure such as the oaks, maples, etc. Without definite knowledge we should therefore expect to find a decrease in the strength of wood boiled in creosote, particularly if the boiling reduces the moisture in the wood much below its fiber-saturation point. Information on this point is meager. Some green Douglas fir bridge stringers boiled in creosote and then impregnated with the oil showed about 40 percent loss in strength over similar stringers untreated. This decrease was, apparently, permanent, because a year's seasoning after treatment showed approximately the same results. One example does not, of course, prove that the

weakening was caused by the boiling, as it may have been due either to the heat or the oil. The shrinkage of timber boiled in oil is very rapid and its quite possible that this rapid shrinkage may produce injury by setting up a complex series of stresses in the wood. Whether or not this is the case and the extent to which it may affect the various woods is not known at the present writing.

**The Effect of Preservatives on the Strength of Wood.**—This is a much discussed problem on which little conclusive data is available. A number of tests have, however, been made and from them certain deductions can be drawn. The preservatives which have been tested are creosote, zinc chloride, and crude oil.

*Creosote.*—It has commonly been supposed that creosote does not enter the cell walls of wood and for this reason could have, *per se*, little or no effect on the strength of wood. Careful tests by Teesdale[1] have shown that creosote enters the cell walls and will cause them to swell. The amount which is absorbed by the walls in practice is, however, insignificant compared with the total amount injected. We should expect, therefore, that creosote has but little weakening effect on the strength of wood treated with it. Tests made on creosoted wood, tend to substantitate this (Table 6), these being made on small clear specimens impregnated with about 8 pounds of oil per cubic foot. Green loblolly pine steamed and creosoted with about 20 pounds of oil per cubic foot showed no loss in strength over the ties which were simply steamed and then tested. In fact, in creosoting loblolly pine without steaming, the creosoted wood tested higher than the untreated wood, the process apparently having a tendency to dry the wood.[2] Some full-sized longleaf pine bridge stringers steamed, creosoted by the Bethel process with 12 pounds of oil per cubic foot and then tested, showed no apparent loss in strength over the stringers tested untreated and carefully matched with them. It appears that when the wood is not damaged by the process, creosote in itself will produce little or no weakening of practical significance. There is, however, a possibility that this will not hold for all kinds of wood but at present data to substantiate this is not known.

*Zinc Chloride.*—It is well known that a concentrated solution of zinc chloride will dissolve wood. In practice, the solutions

[1] Circular 200, United States Forest Service.

[2] Circular 39, United States Forest Service.

rarely exceed a strength of 6 percent and at this concentration their action on wood is very slight. The common specification calls for an injection of a half pound of dry zinc chloride per cubic foot of wood. Assume the wood after treatment will season to 10 pounds of water per cubic foot and the preservative has been diffused through it. This will give a strength of only 5 percent. If, however, the solution only penetrates the outer fibers of the wood and the zinc chloride concentrates itself in these fibers, it may reach sufficient strength to do actual harm. In this condition the wood is said to be "burnt" or "killed" and is invariably the result of poor workmanship. Proper treatments use as weak solutions as possible in order to get the requisite absorption, and thus avoid any liability to injury of the wood fiber. Green loblolly pine treated with zinc chloride solutions of various concentrations and then tested in static bending, compression parallel to the grain and in impact bending, gave the following results when air dried to about 13 percent moisture.[1]

| Strength of solution | Average strength in percent of steamed wood |
|---|---|
| 2.5 | 98.0 |
| 3.5 | 95.1 |
| 5.0 | 91.8 |
| 10.0 | 91.8 |

The conclusions drawn from these and similar tests is that zinc chloride when properly injected into wood will not weaken it to any appreciable extent under static loading, but apparently tends to render it brittle under impact, especially when strong concentrations are used.

*Crude Oil.*—Crude oil when heavily injected into wood apparently weakens it. Thus some loblolly pine, shortleaf pine and red gum ties, impregnated with about 14 pounds of crude oil per cubic foot, gave only 73, 72, and 90 percent respectively of the strength of the same kind of ties untreated, whereas the ties treated with creosote and zinc chloride showed no loss whatever.

**The Effect of Temperature on the Strength of Wood.**—Heat tends to weaken wood, cold to stiffen it. In this respect wood, therefore, behaves like a plastic material. Tiemann[2] has made some careful researches along these lines, and the results secured by him have been substantiated by further tests. He has soaked

[1] Circular 39, United States Forest Service.

[2] Bulletin 70, United States Forest Service.

pieces of longleaf pine, spruce and chestnut in water for various periods and then tested them at various temperatures. The general results are shown in Table 36. The tests designated "cold" were made when the wood was at temperatures ranging from 7° to 19° F.; those marked "warm" at 45° to 68° F. An examination of all the results shows a decided increase in both the strength and stiffness of the frozen pieces, excepting the very dry wood. Of course, in treating operations the timber is seldom frozen, although this at times occurs. On the other hand, the temperatures in the cylinder frequently rise to 250° F. It is doubtful whether this is sufficiently high to cause in itself any permanent weakening in the wood, so that after the timber has again reached atmospheric temperature no weakening due to the temperature of treatment has any practical significance.

TABLE 36.—THE EFFECT OF TEMPERATURE ON THE STRENGTH OF WOOD
(Specimens about 2 × 2 × 5.75 inches)

| Kind of wood | How tested | Moisture at test, percent | Crushing strength, lb. per sq. in. | Modulus of elasticity, lb. per sq. in. |
|---|---|---|---|---|
| Longleaf pine. | cold | 23 | 6,440 | 1,418,000 |
| | warm | 24 | 5,750 | 1,360,000 |
| Spruce | cold | 27 | 4,060 | 894,000 |
| | warm | 22 | 3,923 | 753,000 |
| Chestnut | cold | 68 | 3,180 | 708,000 |
| | warm | 72 | 2,622 | 553,000 |

## THE EFFECT OF PRESSURE ON THE STRENGTH OF WOOD

Pressures used in treating timber are all far too low to cause any weakening of the wood. A pressure of 200 pounds per square inch is about as high as is ever held and even this is much below the crushing strength of our weakest commercial woods. It is quite probable that the wood during treatment undergoes a slight decrease in volume (less than 0.5 percent in general woods) due to the pressure used, but that on the release of pressure this is fully recovered.

**The Effect of Various Treatments on the Strength of Wood.**—We have now considered the individual effect of the various units in the treatment of timber upon the strength of the timber. Let us now consider their combined effect as shown by some tests on treated wood. For this information we are indebted to Dr. W. K.

Hatt, who tested a number of ties treated by various processes at commercial plants. In other words, no attempt was made to study more than the added effect of all factors entering into the treatment in order to ascertain whether or not the treatment decreased the strength of the ties over similar ties untreated. The results of these tests are shown in Table 37.

TABLE 37.—SHOWING EFFECT OF TREATING TIES UPON THEIR CRUSHING STRENGTH AND SPIKE HOLDING POWER[1]

| Kind of wood | Treating process used | Crushing strength at elastic limit perpendicular to grain in percent of untreated tie | Resistance to spike pulling in percent of untreated tie with cut spikes | |
|---|---|---|---|---|
| | | | Cut spikes | Screw spikes |
| Red oak | Untreated | 100 | 100 | 173 |
| | Burnettized | 97 | 98 | 172 |
| | Lowry | 104 | 93 | 163 |
| | Rueping | 92 | 93 | 162 |
| | Full cell | 104 | 101 | 172 |
| Loblolly pine | Untreated | 100 | 100 | 215 |
| | Rueping | 99 | 123 | 209 |
| | Lowry | 104 | 94 | 219 |
| | Rueping | 112 | 109 | 246 |
| | Full cell | 100 | 84 | 184 |
| | Crude oil | 73 | 53 | 192 |
| Shortleaf pine | Untreated | 100 | 100 | 241 |
| | Rueping | 103 | 100 | 209 |
| | Full cell | 108 | 103 | 223 |
| | Crude oil | 72 | 45 | 176 |
| Longleaf pine | Untreated | 100 | 100 | 202 |
| | Rueping | 109 | 100 | 205 |
| | Full cell | 101 | 105 | 270 |
| Red gum | Untreated | 100 | 100 | 228 |
| | Rueping | 97 | 102 | 222 |
| | Full cell | 99 | 105 | 252 |
| | Crude oil | 90 | 70 | 270 |

[1] A part of the differences in strength here noted are due to varying moisture contents of the ties and the fact that different ties had, of course, to be used, it being impossible to keep these absolutely uniform.

Data taken from experiments made under the direction of Dr. W. K. Hatt and published in the bulletins of the American Railway Engineering Association.

It will be noted that all the treatments show little or no decrease in strength with the exception of crude oil. The increases noted may be due to superior wood in the treated ties or to their having dried out more than the untreated ties or to a combination of these two. Of course, all these conclusions presuppose that the treatments were properly made and are normal. Bad management on the part of the treating engineers would, undoubtedly, have yielded entirely different results.

**The Electrical Resistance of Wood Treated with Creosote and Zinc Chloride.**—This a matter of considerable importance to steam railroad companies in the operation of their block signals, to electric traction companies in the return of their current, and to telephone and hydro-electric companies in the seepage of current carried in wires over their poles. As is usual in problems of this kind, the opinions of operating men vary considerably, and little agreement is found. Mr. J. T. Butterfield conducted some interesting and valuable experiments on this problem at Purdue University in 1910, with ties treated at commercial plants, the following information being taken from his work:

"The resistance was measured by the method commonly used for measuring the insulation resistance of electrical machinery, namely, by means of a direct-current voltmeter of known resistance. This method was applied in two ways. (1) The contact surface for flow of current in the ties was a sawn surface as nearly plane as possible. Contact pressure of 250 pounds per square inch was applied in a Riehle Testing Machine by means of sheet-iron pans, placed one above the other and filled between with dry sand, by which constant surface resistance was obtained. (2) After some of the fundamental laws were investigated, the resistance of the various ties was compared by measuring the current flowing between two spikes driven 20 inches apart in the face of each tie. Then the relation of these latter tests, between the two spikes, to the conditions obtaining in a full tie with rails spiked thereto was investigated.

In beginning the tests the principal elements which cause the resistance to vary were determined and investigated in the following order:

1. Amount of moisture present.
2. Kind of wood.
3. Treatment.
4. Direction of grain.

5. Contact pressure
6. Temperature.
7. Amount and time of current flowing.
8. Dimensions of specimen.

**Moisture.**—The important effect of moisture is plainly shown by the following tables, determined by the testing-machine method:

TEST OF RED OAK

Zinc-chloride treatment 1.7 percent

| Percent moisture | Ohms per cu. in. |
|---|---|
| 14.4 | 3,370,000 |
| 17. | 414,000 |
| 19.1 | 94,000 |
| 27.4 | 2,140 |
| 35.7 | 1,381 |
| 47. | 1,310 |
| 52.2 | 1,100 |
| Untreated | |
| 13.3 | 5,020,000 |
| 17.3 | 784,000 |
| 21.6 | 198,000 |
| 26.6 | 136,300 |
| 38.0 | 7,100 |
| 43.3 | 6,440 |
| 47.3 | 5,070 |

In order to investigate the longitudinal distribution of resistance through a tie, a number were cut up into 6-inch lengths and the resistance measured parallel with the grain. The results plainly showed that there was an enormous resistance at the ends of a tie, which may have a uniformly low resistance in the interior. The cause for this high-end resistance was, of course, the drying out of the ends.

### KIND OF WOOD AND TREATMENT

In measuring the resistance of different woods, the method used was that of determining the resistance between two spikes, as described above. The ties were generally tested in the yard and had been piled. Some were covered and were no doubt less dry than others. Variation in resistance of untreated ties of same species is to be accredited to moisture variation. Generally tests of 5 treated and 15 natural ties enter into the average.

| | Resistance (megohms per half tie) Natural | Treated | Ratio of, treated to natural |
|---|---|---|---|
| **Lowry Creosote Process** | | | |
| Red oak | 0.182 | 0.177 | 0.973 |
| **Rueping Process** | | | |
| Loblolly pine | 5.58 | 5.05 | 0.91 |
| Shortleaf pine | 2.97 | 1.035 | 0.35 |
| Longleaf pine (very dry) | 5.4 | 6.05 | 1.12 |
| Red gum | 0.39 | 0.22 | 0.58 |
| Loblolly pine | 1.46 | 1.41 | 0.96 |
| **Full-cell Process** | | | |
| Loblolly pine | 2.94 | 1.00 | 0.34 |
| Shortleaf pine | 3.41 | 2.70 | 0.79 |
| Longleaf pine | 1.80 | 2.2 | 1.22 |
| Red gum | 0.225 | 0.28 | 1.24 |
| Loblolly pine | 4.47 | 0.905 | 0.20 |
| **Zinc Chloride Process** | | | |
| Red oak | 0.08 | 0.0125 | 0.156 |

## DIRECTION OF GRAIN

The direction of the grain has a decided effect upon the resistance of wood, and as the resistance of ties was taken parallel with the grain, little consideration was given the question aside from the following tests:

Resistance in Megohms

| Kind of wood 3-in. cubes, air dried | Lengthwise | Radial to growth rings | Tangential to growth rings | Percent moisture |
|---|---|---|---|---|
| Natural red oak | 0.0175 | 0.12 | 0.15 | 25 |
| Natural red oak | 0.0175 | 0.041 | 0.07 | 40 |

## CONTACT PRESSURE

The study of the effect of contact pressure on a number of different specimens held between contacts in the testing machine and involving the longitudinal resistance corresponding to different loads developed the following results. As would be expected, it was found that the resistance decreases rapidly with increase of contact pressure.

Red Oak, Zinc Chloride Treatment, 3-in. Cubes

| Lengthwise of grain Lb. per sq. in. | Air dried Ohms |
|---|---|
| 500.0 | 175 |
| 278.0 | 180 |
| 56.5 | 220 |
| 22.2 | 270 |
| 8.9 | 460 |
| 3.3 | 575 |
| 1.0 | 1550 |
| 0.0 | 5850 |

Red Gum, Natural, 3-in. Cubes

| Lengthwise of grain | Air dried |
|---|---|
| 55.5 | 26,400 |
| 33.3 | 26,800 |
| 22.2 | 27,700 |
| 15.5 | 30,350 |
| 11.0 | 32,700 |
| 7.9 | 33,000 |
| 5.5 | 39,400 |
| 0.0 | 67,000 |

## TEMPERATURE

Some preliminary tests were made upon the ties to discover the effects of temperature. The results, although not capable of representation by a smooth curve, showed that the resistance decreased with an increase of temperature in a nearly direct proportion.

Red Oak

Zinc chloride treatment—testing machine method. End of grain

Block = 5 × 8 × 6 inch

Temperature = average of six thermometers

| Temperature, degrees C. | Resistance, ohms |
|---|---|
| 0.33 | 2500 |
| 3.65 | 2100 |
| 5.70 | 1945 |
| 7.50 | 1820 |
| 10.70 | 1560 |
| 12.20 | 1270 |
| 14.50 | 1050 |
| 16.70 | 910 |
| 21.00 | 670 |
| 22.50 | 623 |

## ELECTROLYTIC EFFECT

While measuring a low resistance in the testing machine with a high voltage it was noticed that the voltmeter needle tended to fall back rapidly if the circuit was allowed to remain closed for a short time. This pointed to some kind of an electrolytic effect, and some tests were therefore made in which the current was allowed to flow for some time until the resistance became nearly constant. Then the circuit was opened and the specimen allowed to recover. The following are the results:

ELECTROLYTIC EFFECT

Natural red oak. 60 percent moisture

| Time | Volts | Ohms per cu. in. |
|---|---|---|
| 0.00 sec. | 13.00 | 1010 |
| 0.15 sec | 12.80 | 1130 |
| 0.30 sec. | 12.70 | 1190 |
| 1.00 min. | 12.61 | 1248 |
| 2.00 min. | 12.55 | 1288 |
| 3.00 min. | 12.50 | 1320 |
| 4.00 min. | 12.47 | 1340 |
| 6.00 min. | 12.41 | 1380 |
| | Circuit opened | |
| 7.00 min. | 12.40 | 1386 |
| 8.00 min. | 12.79 | 1140 |
| 9.00 min. | 12.86 | 1101 |
| 10.00 min. | 12.92 | 1056 |
| 11.00 min. | 12.92 | 1056 |

## INFLUENCE OF VOLUME

The relation of resistance to the dimensions of the specimen was plainly showed to vary the same as with any conducting material.

RED OAK—ZINC CHLORIDE TREATMENT

| Length | Section | Resistance, ohms |
|---|---|---|
| 6 in. | 3 sq. in. | 9,790 |
| 9 in. | 3 sq. in. | 16,030 |
| 12 in. | 3 sq. in. | 22,500 |
| 15 in. | 3 sq. in. | 35,500 |

RED OAK—NATURAL

Length 3 in. Cross section varied

| Cross section, sq. in. | Resistance, ohms |
|---|---|
| 9 | 6,000 |
| 18 | 11,000 |
| 27 | 16,000 |
| 36 | 22,000 |

**RELATION OF TESTS BETWEEN SPIKES TO ACTUAL TIE**

A few tests were made with rails spiked to a whole tie, and the resistance measured and compared to the resistance of spikes 20 inches apart.

The resistance between the rails spiked to the whole tie was found to be about 18 times the resistance between spikes driven 20 inches apart and 4 1/2 inches in the face of the tie.

The moisture condition of the surface of the tie was artificially varied.

H = The percentage increase in conductivity between rail and tie, due to rail bearing. For example, the value of H = 0.95 for oak ties is found as follows:

$$H = \frac{\frac{1}{44400} - \frac{1}{44800}}{\frac{1}{44800}} \times 100 = 0.95 \text{ percent.}$$

**CONDUCTIVITY OF TIE WITH RAILS SPIKED THERETO AS COMPARED WITH SPIKES ALONE**

Section of 85-pound Rail Spiked to Ties at Standard Gage Distance. No. 6 is Red Oak. No. 7 is chestnut

| Condition of tie | | Ohms. H. | Percent. |
|---|---|---|---|
| Dry; spikes only | No. 6 | 44,800 | 0.95 |
| | No. 7 | 9,500 | 2.16 |
| Dry; with rails | No. 6. | 44,400 | .... |
| | No. 7. | 9,300 | .... |
| Wet at rail bearing; spikes only | No. 6. | 43,700 | 0.93 |
| | No. 7. | 9,400 | 6.79 |
| Wet at rail bearing; with rails | No. 6. | 43,300 | .... |
| | No. 7. | 8,800 | .... |
| Wet all over; with rails | No. 6. | 27,800 | .... |
| | No. 7. | 7,760 | .... |
| Bottom of tie in wet gravel; with rail | No. 6. | 10,270 | .... |
| Tie in moist gravel ballast; with rail | No. 7. | 4,350 | .... |
| Tie in very wet ballast; with rail | No. 6. | 6,780 | 7.68 |
| | No. 7. | 3,220 | 6.52 |
| Same as above; spikes only | No. 6. | 7,300 | .... |
| | No. 7. | 3,430 | .... |

The resistance of the bearing between a newly spiked dry rail and a dry red-oak tie will be found to be approximately 1 percent of the total conductivity of the tie, but after the spikes have loosened the pressure on the rail bearing is about the

weight of rail per tie divided by the area of the bearing. This is about 2 pounds per square inch. Such light pressure means high contact resistance. Considering the further fact that the crosswise resistance of a tie is several times its lengthwise resistance per unit of length, and that all leakage current through the rail bearing must pass through a considerable amount of cross-grain resistance, the total resistance of the leakage path between rails is very high.

## CONCLUSIONS

The results obtained tend to establish the following conclusions:

Timber is ordinarily classed with the nonconductors. When dry and well seasoned, it has a very high dielectric strength and practically infinite resistance. When green or moist, however, timber becomes a kind of electrolytic conductor of comparatively low resistance. The treatment with zinc preservatives has the simple effect of producing in the wood a stronger electrolyte and hence a better conductor of current.

1. The resistance of timber varies directly with the length and inversely with the cross section.

2. The resistance of timber varies almost inversely with the amount of moisture present, between the limits of 15 and 50 percent.

3. The resistance of timber is lowest when measured along the grain, and highest when measured tangentially to the growth rings.

4. When treated with a soluble salt such as zinc chloride, the resistance varies approximately inversely as the amount of the salt present.

5. Treatment with such a soluble salt does not change the behavior of the resistance with respect to the percent moisture present. Only the amount of the resistance is changed.

6. The resistance of timber varies almost inversely with the temperature between the limits of zero and 50° C.

7. The resistance of nonporous woods, such as the pines, is higher than that of porous woods, such as the oaks and red gum.

8. Treatment of timber by different creosote processes does not greatly change the natural resistance of the timber.

9. Finally, all the data taken goes to establish the view that

the conductivity of wood is due primarily to the presence in the pores of an electrolyte formed by an aqueous solution of the salts found in the natural timber, or of these salts and others artificially introduced.

Assuming the worst condition for leakage covered by the test, *i.e.*, red oak ties treated with zinc chloride laid in wet ballast and with wet rail bearings, the resistance between the rails of a block 1 mile in length would approximate 30 ohms. This would permit a leakage current of 0.05 ampere to flow with the battery voltage of 1.5 volts. The leakage loss would, therefore, be 0.075 watt, or about 30 percent of the power required to operate the relay. This sholud not seriously interfere with the operation of signals, as leakages up to 60 percent exist without such serious interference.

It is to be regretted that determinations of resistance were not made with wet ties or with ties and rails partially immersed in water, as is sometimes the case in practice, for it is believed that under such conditions the leakage current would probably be sufficiently large to interfere with the successful operation of relays.

As a final conclusion, it should be noted that since the above results show only a reduction in resistance of a tie of from 26 to 53 percent when treated with zinc chloride, depending upon the percentage of moisture, while a change of resistance by the ratio of 25 to 1 may be effected by varying the kind of wood, a change of 33 to 1 by varying the pressure upon the tie sufficiently, and of 3.7 to 1 by temperature changes, it follows that the treatment of ties with preservatives should not interfere with the operation of signal circuits, except possibly in exceptional cases in which the resistance of the leakage paths is abnormally low from other causes."

From a number of inquiries, it is the experience of several signal engineers that little or no difficulty will be experienced with zinc treated ties if the distance between signal blocks is not too great and if the ties are not laid green. Some of them have shortened the distance between signals to about 1000 to 1200 feet and report complete satisfaction. Against creosoted ties no complaint on this account is made.

A number of traction companies state that the zinc-treated ties corrode their spikes very rapidly and for this reason they are opposed to using them. It is entirely possible that this will occur,

especially if the ties are liable to hold much moisture and are situated a long distance from the power house. Ties which can be kept fairly dry, and can be laid close to the power house so that the return current will be through them, rather than away from them, should give little trouble.

The leakage in current in poles and cross arms treated with soluble salts should be very slight and of little or no practical consequence since they are not counted upon for insulation, this being taken care of by the insulators themselves. However, it seems entirely probable that creosoted poles and arms will tend to resist leakage more than those which are salt treated because they will, in general, contain less moisture. As already stated, such a difference can at most have little practical significance and for this reason treated poles can undoubtedly be used in the same manner as untreated poles.

## CHAPTER XIX

## THE USE OF SUBSTITUTES FOR TREATED TIMBER

By the term "substitute" is here meant a material which is offered in place of wood, wood having been the standard. Thus, although wood and asphalt are both used extensively for street pavements, asphalt is not considered a substitue for wood but a competitor of wood. On the other hand a concrete tie is a "substitute" for the wood tie. With this distinction in mind, a clearer conception of the inroads being made by other materials can be had. It is not intended to discuss in this chapter the general substitution of other materials for wood but only for treated wood. This has taken place in a wide variety of products and, in certain instances, is making rapid headway. It is caused by the rise in the price of timber, the demand for better construction and an improvement in the manufacture of the substitutes.

**Substitutes for Wood Ties.**—This was one of the first fields entered and thousands of dollars have been spent in attempting to find a satisfactory substitute for wood ties. Ties made of steel, concrete, leather, and combinations of these materials have all been tested both in this country and abroad. Best success has been had with the steel ties, but their introduction has been very slow, and the results secured from them by no means all that is required. The American Railway Engineering Association has gone rather extensively into this problem and has made a report containing much valuable data.[1] It states that "an improved form of steel tie, as shown in Plate XXII, Fig. C, of the type manufactured by the Carnegie Steel Co. with metal plate over the insulating fiber and with the wedge clip rail fastening, seems to be very promising." A few railroads report satisfactory experience with the steel tie, while other companies have discarded them. The general consensus of opinion at present seems to be that these ties are still in the experimental stage but worthy of trial.

As a result of its studies, the American Railway Engineering

[1] Bulletin 108, American Railway Engineering Association, 1909.

Association committee concludes "that no form of reinforced concrete tie has been made which is suitable for heavy and high-speed traffic, but believes a properly reinforced concrete tie, with proper fastenings, may be found economical in places where speed is slow and where conditions are especially adverse to the life of wood or metal." The Lake Shore & Michigan Southern Railroad placed some "Buhrer Concrete Ties" in its track at Sandusky, Ohio, in 1904. There were no renewals up to 1908 and all the ties appeared in good condition. The more common experience, however, seems to be like that of the Pennsylvania Railroad, which placed 500 of these ties in 1903. "The concrete broke and crumbled and by December, 1906, all had been removed on account of breaking." Kimball, Percival, Affleck, Chenoweth, Keefer, Hickey and Alfred concrete ties tested by various railroads all cracked or crumbled in 2 or 3 years although in a few cases longer lives were secured. It appears, therefore, that a satisfactory substitute for the treated wooden tie still remains to be found.

**Substitutes for Wood Poles.**—Iron, concrete and glass have been tested for poles. In cities, the iron pole has given very good use and has very largely replaced the wood poles. However, in the larger cities, even the iron pole has been done away with, except for street lighting, its place being taken by conduits. Wood poles are still used in large quantities in towns and cities and in the country for trolley, telephone, telegraph and high power transmission lines, although with the latter, steel towers furnish the best construction. Concrete poles are largely in the experimental stage as yet. Poles 100 feet or more in length have, however, been constructed of reinforced concrete. On account of their great weight, high cost, and difficulty of handling, it is doubtful whether concrete poles will make serious inroads on wood poles for years to come, except perhaps in isolated cases. Concrete poles have not been in service long enough to know their merits.

Glass poles are purely an experiment and, from the results secured thus far, success seems doubtful.

A review of past experiences shows that only in large cities has any material been successfully substituted for wood in the manufacture of poles, and that no substitute which gives promise of extended usage is in demand.

**Substitutes for Wood Piling.**—Wrought iron, cast iron, steel and reinforced concrete have all been used for piles. Iron in all its forms is, of course, free from attack by the marine borers.

It corrodes, however, when driven in sea water. Wrought iron apparently corrodes more rapidly than steel which contains about 0.1 percent of carbon. Cast iron becomes pitted, the iron being gradually dissolved leaving the carbon. The life of iron piles is not known, but from tests made by various investigators, it appears that wrought iron and steel will corrode at the rate of about 0.40 inches per 100 years. The actual usefulness of the pile will depend largely upon the extent to which it becomes pitted and apparently this varies between very wide limits.

Reinforced concrete piles have been used since 1896 and large numbers have been placed in various harbors of the world. These piles, are attacked at times by the sea water, which disintegrates them. Furthermore, alternate freezing and thawing have, in cases, cleaved off much of the concrete. Yet in spite of these difficulties, concrete piles possess considerable merit and give promise of being perfected to an extent where they will prove free from these objections. Concrete piles have not been used sufficiently long or driven in sufficient numbers and under such conditions as to furnish reliable data on their probable life.

**Substitutes for Wood Posts.**—Considerable progress has been made in manufacturing concrete posts, and several railroads in our country are now using large quantities of them. The cost of making the posts varies from about 16 to 25 cents each. Nothing is known of their life, but this is estimated by several manufactures to be at least 40 years. Concrete posts are heavy, troublesome to make, liable to be thrown by frost heave, require careful handling and have other ills, but in spite of them all, they possess much merit, particularly because of their durability and appearance, and have unquestionably come to stay and their consumption will increase. (See Plate XXII, Fig. D.)

Posts are also made of cast iron, iron pipe and galvanized sheet iron, but the number is so small as to be insignificant and probably will always remain so, except for a comparatively few special cases.

**Substitutes for Wood Mine Timbers.**—Concrete, masonry and steel have all been substituted for wood mine timbers, but only in isolated cases. Concrete mine timbers are very expensive, their installation interferes with the working of the mine and in some cases they are crushed before they become "set." It is doubtful if they will come into general use. (See Plate XXII, Fig. A.) Iron mine "timbers" have been tested both here and in

Europe. They are expensive, difficult to install, and are corroded by the mine gases and water. Furthermore, if the mine once starts to "cave," the iron "timbers" will fail although they will, of course, hold a greater load than wood. In Europe a unique method in the design of iron props has been tested. It consists of two hollow pipes, one of which fits snugly inside the other. Round iron balls are then placed in the lower pipe. In this manner the upper pipe can be extended and held by the balls, preventing further telescoping. When it is desired to remove the prop, a plug in the lower pipe is opened and the balls allowed to roll out. This makes a prop which can be fitted into place. Its cost, of course, is high and in addition it is subject to most of the objections raised against iron mine "timbers." Our largest iron and steel company is using enormous quantities of wood in its own mines, some of which is treated with preservatives. Masonry, is, of course, out of the question because of its high cost, trouble in laying, etc., except for very unusual situations, so it doubtless will never become a serious rival to other forms of "timbering."

**Substitutes for Wood Bridge Timbers.**—Steel, masonry and reinforced concrete have almost entirely replaced wood in the construction of permanent bridges. In addition to possessing greater strength, such bridges are less subject to destruction by fire. In so far as durability between steel and wood bridges is concerned, doubt still exists in the minds of some engineers and confiicting data have been submitted. Creosoted wood bridge timbers are known to have existed in perfect condition for over 30 years in the South where decay is generally rapid. Apprehension of the gradual deterioration ("fatigue") of such timber due to repeated impacts, does not appear well founded. Some railroads in our country are laying creosoted bridge timbers on top of steel members, thus adding to the elasticity of the bridge and deadening of sound. Considerable quantities of wood are still used on steel bridges in the form of ties, guard rails, wall plates, etc., and in wooden bridges and trestles, but as the demand for high grade permanent structures increases, the use of wood will unquestionably decrease. It is likely, however, that a demand for wood shields under steel bridges which are subject to corrosion from the locomotive stacks will increase, especially when the wood is rendered noninflammable.

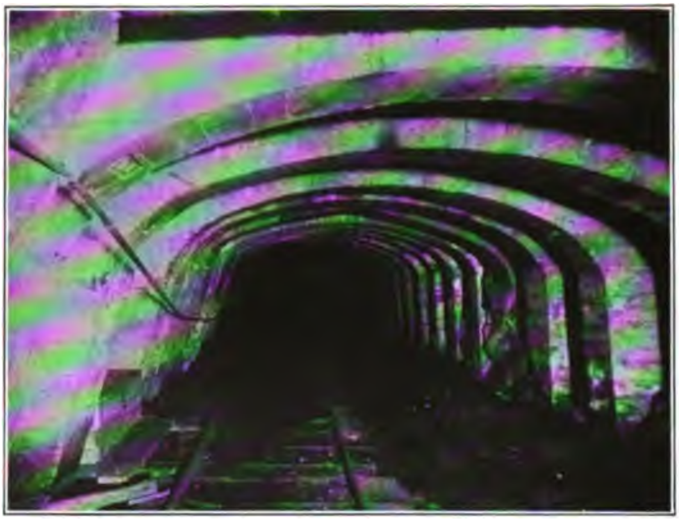


FIG. A.—Concrete mine props, Pennsylvania. (Forest Service photo.)

FIG. B.—Indiana Tie Company's wood preserving plant, Joppa, Ill. Note depressed tracks and manner of running cylinder cars on flat cars for loading ties into box cars for shipment.

(Facing page 246.)

FIG. C.—Nest box used to protect poles and buildings from attack by woodpeckers. (Photo courtesy Ernest Baynes.)

FIG. D.—Wood dowels screwed into softwood ties as a protection against spike cutting.

**Substitutes for Wood in Buildings and Cars.**—As only small quantities of treated wood are used in the construction of buildings and cars, the substitution of other materials affects but little the wood preserving industry.

A special committee of the American Railway Association appointed in 1912 circularized the railroads of the United States and received reports from 247 railroad companies operating 227,754 miles of track. The object of the circular was to ascertain the progress being made in introducing steel passenger cars in place of wooden cars. The following table summarizes the findings of this committee:

| | Total number | Steel, percent | Percentages steel Uner frame | Wood, percent |
|---|---|---|---|---|
| 1909.............. | 1880 | 26.0 | 22.6 | 51.4 |
| 1910.............. | 3638 | 55.4 | 14.8 | 29.8 |
| 1911.............. | 3756 | 59.0 | 20.3 | 20.7 |
| 1912.............. | 2660 | 68.7 | 20.9 | 10.4 |
| January, 1912....... (Under construction) | 1649 | 85.2 | 11.5 | 3.3 |

The substitution of steel for wood in freight cars is also taking place at a rapid rate. While opinions vary widely at present, it appears that a combination of steel and wood will be the ultimate solution of many of the freight car problems. Similar changes are taking place in the construction of buildings in cities where the tendency is to reduce the fire hazard to a minimum. Steel, concrete, and clay products have replaced wood to a very large extent and there is little doubt but what such replacement is permanent. In certain cases, however, a reaction has set in, as it was found that many buildings supposedly "fireproof" were really not so when put to the test. Thus wood floors and trim will probably remain for years to come. "Slow burning" factory construction has also been in demand. It is believed that "fireproofing" wood used in such buildings will do much to remove some of the serious objections raised against wood and that this phase of the wood-preserving industry will grow to much larger proportions than at present.

**Substitutes for Wood Shingles.**—There is a great variety of roofing materials such as metal, slate, tile, asbestos, etc., now on the market which are replacing shingles. This has been brought about largely through the demand for fireproof construction—

certain cities having passed ordinances prohibiting the use of wood shingles within their congested limits. As buildings become more crowded and permanent, wood is invariably replaced. In general, roofs built of these "substitute" materials cost more than shingle roofs, not only for the covering itself, but for the construction necessary to hold up the greater weight. It is possible that the progress being made in "fireproofing" shingles, will do much to retain their existence. If this one very serious objection could be removed, wood shingles would remain in favor. They possess certain characteristics such as cheapness, ease of repair, light weight, adaptability to artistic design, durability, resistance to heat transmission, etc., which are in strong demand.

**Substitutes for Wood Conduits and Pipes.**—The use of treated wood for these purposes is quite small, and forms but a small percentage of the total amount. Fiber conduit, tile, brick, and steel are all used in large quantities. Creosoted wood conduit is very durable and has given excellent service. It is comparatively inexpensive, easily laid and resistant to injury from settlement of the surrounding earth. The oil will, of course, attack rubber and under certain conditions cannot be used. Large quantities of wood have been used in building pipes, particularly for irrigating purposes. One decided advantage seems to be a lowering in the coefficient of friction through use—a result quite the opposite of metal, which tends to become rough and hence decrease the quantity of water which flows through it.

# CHAPTER XX

## APPENDICES

**Minor Wood-preserving Processes.**—No attempt is made to list and describe all of the various processes which have been advanced in this country to preserve wood from decay. To do so would prolong this book to several volumes. Some idea of the number of wood-preserving processes suggested can be gained by examining the list of patents given below. But to inform those who might wish information on this phase of wood preservation, a number of the better-known and more interesting methods will be briefly discussed. Some of them may eventually be extensively practised in our country.

**Thilmany Process.**—Patented by Thilmany in 1876, the process consists in impregnating wood with copper sulphate (later zinc sulphate was substituted) followed by a second injection of barium chloride. The object was to produce a chemical reaction giving copper chloride and barium sulphate; the latter being insoluble in water was intended to plug the wood and prevent the copper chloride from leaching out. The process was tested by several railroads in this country without apparent success.

**The B-M Timber-preserving Process.**—This process uses a combination of zinc chloride and aluminum sulphate as covered by patents held by Hubertumühle of Schöpfurth, Mark, Germany. It is claimed that the aluminum sulphate is not only an antiseptic salt, but gives a better solution to the zinc chloride and carries this salt deeper into the wood. It is also claimed to combine in part with the wood structure. The solution is injected into timber much in the same manner as zinc chloride in the Burnett process except that the temperatures are kept somewhat lower. From analyses of treated wood made by certain reputable chemists, it appears that better penetrations are secured in the B-M process than in the straight Burnett process. Some treating companies in the United States are now ready to treat timber by this process.

**The Goltra Process.**—Named after W. F. Goltra of Cleveland, Ohio. For handling ties the distinct steps in the process are:

(*a*) Steaming ties upon delivery at plant.
(*b*) Stacking ties for open-air seasoning.
(*c*) Machining ties.
(*d*) Drying and warming ties in ovens.
(*e*) Impregnation with antiseptic liquid.

The novel features in the process are the steaming of the ties on delivery at the plant and then air-seasoning them; also warming the ties in ovens before injecting the preservative. So far as the author knows, this process is not in commercial use, although it has been considerably agitated in the past few years.

**The Hasselman Process.**—Patented in the United States in 1897. This process consists essentially in injecting into wood a solution containing sulphates of iron and aluminum to which "Kainit" is added to neutralize the free acids which may be formed. The process was tested experimentally in Texas with poor results. Since then certain modifications of the process have been proposed by Barschall and some timber treated in this manner is now under test by the United States Forest Service with no conclusive results to date.

**The Creo-Resinate Process.**—First practised by the United States Wood Preserving Company, particularly for the treatment of paving blocks. The wood is subjected to a dry heat, after which a vacuum is drawn and the creo-resinate mixture forced into the wood. This mixture consists of creosote (about 50 percent), 48 percent rosin, and 2 percent formaldehyde. A subsequent treatment with a solution of lime is then given. It is understood that the original treatment has undergone considerable change since it was first advocated.

**Robbins' Process.**—Practised by the Suffold Wood Preserving Company of Boston about 1869. It consisted in passing vapor of naphtha into the retort after the wood had been run into it, the vapor being heated to about 250–300° F. This vapor was to expel the water from the wood, coagulate the albumen, and expand the wood pores. The temperature in the retort was then raised to 400° F. and vapor of creosote passed into the wood. The process was tested extensively, but failed.

**Powell Process.**—This is an English process which has been tested extensively abroad but is little known in our country. It consists in boiling wood in a solution of sugar for a few hours

and then drying it in an oven at high temperatures. It is said to render wood resistant to ants and decay and nonabsorptive to water. Tests known to the author indicate the process has decided merit in overcoming the hygroscopicity of wood.

**Creoaire Process.**—Advertised by the International Creosoting & Construction Co. It consists in treating wood similar to that employed in the full-cell creosote process, but after the desired amount of oil is forced into the timber the cylinder is drained of excess oil and an air pressure applied to drive the oil further into the wood, thus producing an "empty-cell" effect. Tests made by the author show that this method drives considerable oil out of the wood and may cause "bleeding."

**Vulcanizing Process.**—Practised by the New York Vulcanizing Company of New York City. Sometimes called "Haskins' process." The timber is placed in the treating cylinder. Air compressed to 150 to 200 pounds per square inch is then forced into the wood through a water separator to remove moisture, and heated to about 400 to 500° F. for about 8 hours. The process rapidly removes the water from the wood, and producing a partial distillation, is claimed to render it antiseptic. A large number of ties have been treated by this process, some of which gave long service.

**Cresol-calcium Process.**—This is a Swedish process not practised in this country except experimentally. Agents are Blagden-Waugh Company of London. The timber is handled much as in Burnettizing except that the solution consists of a mixture of milk of lime and crysilic acid resulting in calcium crysilate. It is under test in several places in the United States but apparently with little success.

## PATENTED, PROPRIETARY, AND MINOR WOOD PRESERVATIVES USED IN THE UNITED STATES

A number of wood preservatives which fall under this heading are used in the United States, few of them in any appreciable amount. Perhaps the best known are the "carbolineums," which are used quite extensively, especially for brush-treating timber.

**Cresol-calcium.**—This is handled by Bladgen-Waugh & Company, London, England, Messrs. Heidenstam and Freidmann being the inventors. It has been tested experimentally

in the United States but is not used commercially here. The results secured thus far have not been very satisfactory. The preservative consists essentially of cresol ("tar acids") and milk of lime mixed in varying concentration up to 15 percent in strength and impregnated in a manner similar to Burnettizing.

**S. P. F. Carbolineum.**—Handled by Bruno-Grosche & Co. of New York City. It is a preservative distilled from tar, which, according to the engineering department of the American Telephone and Telegraph Company, is somewhat similar on distillation to Avenarius Carbolineum. It has been used in this country for many years and has given good results.

**Avenarius Carbolineum.**—Made in Germany, but handled by the Carbolineum Wood Preserving Company of Milwaukee, Wis., and other cities. It is essentially a high-grade distillate of coal-tar specially manufactured and has been used in this country for many years with good results.

**C-A-wood Preserver.**—A foreign-made product handled in this country by the C-A-Wood Preserver Company of St. Louis, Mo., with agencies in other cities. Essentially a high-grade distillate of coal-tar, which has been used in this country for many years with good results.

**Timberasphalt.**—Sold by the Indian Refining Company of New York City. It is an "asphaltic flux" resulting from the refining of crude oil, and has no marked antiseptic properties, relying more on its waterproofing and "plugging" action to preserve wood. It is one of the more recent preservatives placed on the market.

**Preservol.**—Sold by the Newbold Manufacturing Company, 135 Greenwich Street, New York City. Said to be a "creosote" made from beech. It has not been very extensively tested in this country.

**Copperized Oil.**—Handled by the Copper Oil Products Company of New York City. It is an oil containing copper. The kind of oil used and amount of copper it contains apparently can be varied for specific requirements. It is one of the new preservatives placed on the market.

**Sodium Silicate.**—Made by several companies in the United States. It does not readily penetrate wood, but has a marked tendency to decrease the inflammability of wood.

**Spirittine.**—Manufactured by the Spirittine Chemical Com-

pany of Wilmington, N. C. This is a special "creosote" made from coniferous wood, and has been used quite extensively in the United States with good results.

**B. M. Preservative.**—The agent in this country is Franz Workman, 31 Liberty Street, New York City. It is a mixture of zinc chloride and normal aluminum sulphate, and has been tested experimentally on a large scale in this country but has not been commercially practised to any appreciable extent. It is forced into wood in much the same manner as in Burnettizing.

**Water-Gas Tar Creosote.**—Made by a number of companies in the United States but seldom sold under its own name. Often mixed with coal-tar creosote. Tests by the U. S. Forest Service show it to have considerable merit as a wood preservative, but not as efficient for general purposes as coal-tar creosote.

**Holz-Helfer.**—Handled by the Vaughn Paint Co. of Cleveland, Ohio, and made in Germany. The wood is either painted with or dipped in the solution. It is a greenish-brown liquid containing zinc chloride, copper, and creosote with a specific gravity at 60° C. of 1.113. From tests made at the U. S. Forest Products Laboratory it appears to be much less toxic than creosote.

**Wood Creosote.**—Made by several companies in the United States but not used extensively. Tests by U. S. Forest Service show it to have considerable merit as a wood preservative and its use for this purpose will quite likely grow, especially for superficial treatments. At present it varies greatly in composition and toxic properties and costs more than coal-tar creosote.

**Sodium Fluoride.**—Made by large manufacturing chemists in the United States. Little known in this country but extensively tested abroad. Experiments by the U. S. Forest Products Laboratory indicate the possibility of using this salt to decided advantage. Further tests are necessary before is full value is known. It is impregnated into wood as in the Burnettizing process.

**Aczol.**—Manufactured by J. Gerlache, Boulevard du Nord, 68 Brussels, Belgium. This is a cuprous-ammonium salt, which is not used to any extent as yet in the United States but is undergoing experiments with the U. S. Forest Service.

**Sapwood Antiseptic.**—Made and patented by J. W. Long, Chicago, Ill. It is a mixture of copper sulphate, sodium chloride, calcium sulphate, zinc sulphate, and iron sulphate with water. Is now undergoing test by the U. S. Forest Products Laboratory and

elsewhere. Is claimed to prevent sap stain as well as decay. Toxic tests show it to possess a very low resistance to fungi.

**N. S. Special.**—Manufactured by the Geo. W. Saums Co, Trenton, N. J. It is a yellowish, oily liqiud with a strong varnish or paint odor. Tests made at the U. S. Forest Products Laboratory show it to have a low resistance to fungi.

**Imperial Wood Preservative.**—This is a comparatively light gravity, greenish-black oil, handled in St. Louis, Mo., containing a high percentage of residue at 315° C. It is under test by the U. S. Forest Service and elsewhere, and is giving results not very unlike those obtained from coal-tar creosote.

**Kreodone.**—This is a special wood-preserving oil made by the Republic Creosoting Company of Indianapolis, Ind., and elsewhere and used largely for preserving wood blocks. It is reported as giving good service.

**Locustine.**—Manufactured by W. H. Huff, Beverly, N. J. It is reported as being a patented compound of nonvolatile petroleum products and certain animal and marine oils and antiseptics, which can be applied to wood either by the brush, dipping, or impregnation processes.

**Creoline.**—This is a very light gravity, brown oil containing much tar acids and water. In spite of this it is giving good results in some test pole lines set under the supervision of the U. S. Forest Service and the Bell Telephone Company.

## LIST OF MANUFACTURERS OF ZINC CHLORIDE IN THE UNITED STATES

General Chemical Co. 112 W. Adams St., Chicago, Ill.
Graselli Chemical Co. Cleveland, Ohio.
Sandoval Zinc Company. East St. Louis, Ill.

## LIST OF MANUFACTURERS OR DEALERS OF CREOSOTE IN THE UNITED STATES

American Conduit Company, East Chicago, Ind.
Armitage Manufacturing Company, Richmond, Va.
American Wood Preserving Company, Chicago, Ill.
Barrett Manufacturing Company, New York, Chicago, and various offices.
Barnay, J. R., Seattle, Wash.
Betts, C. G., Spokane, Wash.
Burton Coal and Lumber Company, Salt Lake City, Utah.
Carolina Portland Cement Co., Atlanta, Ga.

Creosote Supply Co., Chalmette, La.
Chatfield Manufacturing Co., Carthage, Ohio.
Coal-tar Products Company of New York.
Clintock & Irvine Co., Pittsburgh, Pa.
Dominion Tar and Chemical Company, Sidney, Nova Scotia.
Diem & Wing Paper Co., Cincinnati, Ohio.
Denver Gas & Electric Co., Denver, Colo.
International Creosoting Construction Co., Galveston, Texas.
C. Lembcke & Company, New York City.
J. F. Lewis Manufaeturing Co., Chicago, Ill.
National Analine & Chemical Co., New York City.
Nashville Chemical Co., Nashville, Tenn.
Pehlam Bay Chemical Co., Mount Vernon, N. Y.
Pacific Cresoting Co., Seattle, Wash.
Republic Creosoting Co., Minneapolis, Minn.
Semet-Solvay Company, Kingsley, Ala.
Southern Roofing Company, Atlanta.
United Gas Improving Co., Philadelphia, Pa.
Utah Light & Railway Co., Ogden, Utah.
Warren Brothers, Cambridge, Mass.
Western Electric Company, Salt Lake City, Utah.
Zopher Mills, 91 Williams St., Brooklyn, N. Y.

## LIST OF WOOD-PRESERVING PLANTS IN THE UNITED STATES

### EASTERN STATES

| Location of plant | Managing company | Year built | No. of retorts | Diam. retorts (in.) | Length retorts (feet) |
|---|---|---|---|---|---|
| Long Island City, N. Y. | Eppinger & Russell Co. | 1878 | 4 | 72 | 100 |
| Rome, N. Y. | Federal Creo. Co. | 1910 | 2 | 84 | 150 |
| Bound Brook, N. J. | Federal Creo. Co. | 1909 | 1 | 84 | 150 |
| Newark, N. J. | American Creosoting Co. | 1906 | 2 | 78 | 105 |
| Paterson, N. J. | Federal Creo. Co. | 1909 | 1 | 84 | 150 |
| Maurer, N. Y. | Barber Asphalt Pav. Co. | 1905 | 4 | 72 | 115 |
| Port Reading, N. J. | P. & R. R. R., C. R. R. of N. J. | 1912 | 2 | 88 | 140 |
| Greenwich, Pa. | Penna. R. R. | 1910 | 2 | 72 | 132 |
| Mt. Union, Pa. | Penna. R. R. | 1909 | 1 | 72 | 132 |
| Broadford Jc., Pa. | Pittsburgh Wd. Pres. Co. | 1911 | 1 | 84 | 132 |
| Bradford, Pa. | Buff., Roch. & Pgh. R. R. | 1910 | 1 | 75 | 95 |
| Buell, near Norfolk, Va | U. S. Wood Pres. Co. | 1907 | 2 | 78 | 150 |
| Buell, near Norfolk, Va | Norfolk Creosoting Co. | 1896 | 4 | 78 | 100 |
| | | ...... | 1 | 78 | 105 |
| | | 1905 | 1 | 84 | 125 |
| Norfolk, Va. | Atlantic Creo. & Wood Preserving | ...... | 1 | 78 | 62 |
| | Co. | ...... | 1 | 78 | 82 |
| | | 1901 | 1 | 78 | 126 |
| Portsmouth, Va. | Wyckoff Pipe & Creo. Co. | 1881 | 4 | 74 | 102 |
| Green Spring, W. Va. | Balto. & Ohio R. R. | 1912 | 2 | 84 | 132 |

SOUTHERN STATES

| Location of plant | Managing company | Year built | No. of retorts | Diam retorts (in.) | Length retorts (feet) |
|---|---|---|---|---|---|
| Gainesville, Fla. | Atlantic Coast Line R. R. | 1912 | 2 | 74 | 138 |
| Pensacola, Fla. | Southern Pav. Con. Co. | 1912 | 1 | 72 | 90 |
| Jacksonville, Fla. | Eppinger & Russell Co. | 1909 | 3 | 84 | 130 |
| Hull, Fla. | Charlotte Harbor and Nor. Ry. Co. | 1912 | 1 | 74 | 73 |
| Macon, Ga. | Central of Ga. R. R. Co. | 1912 | 2 | 84 | 116 |
| Atlanta, Ga. | Southern Wd. Pres. Co. | 1908 | 1 | 72 | 70 |
| Ensley, Ala. | Pioneer Lum. & Creo. Co. | 1911 | 1 | 74 | 76 |
| Mobile, Ala. | Republic Creosoting Co. | 1906 | 2 | 74 | 130 |
| McAdory, Ala. | Tennessee Coal, Iron and Railroad Co. | 1909 | 1 | 72 | 65 |
| Southport, near New Orleans, La. | American Creosote Wks. | ...... | 1 | 84 | 172 |
| | | 1901 | 1 | 108 | 172 |
| New Orleans, La. | New Orleans Wd. Pr. Co. | 1888 | 1 | 72 | 125 |
| Slidell, La. | Southern Creosoting Co. | 1879 | 1 | 84 | 150 |
| | | 1902 | 2 | 72 | 100 |
| Shreveport, La. | Shreveport Creo. Co. | 1910 | 2 | 84 | 134 |
| Winnfield, La. | Louisiana Creo. Co. | 1906 | 1 | 72 | 126 |
| Bogalusa, La. | Colonial Creo. Co. | ...... | 1 | 72 | 80 |
| | | 1912 | 2 | 72 | 134 |
| Grenada, Miss. | Ayer & Lord Tie Co. | 1904 | 4 | 74 | 128 |
| Gulfport, Miss. | Gulfport Creo. Co. | 1906 | 2 | 84 | 120 |
| Gautier, Miss. | W. Pascagoula Creo. Wks. | 1876 | 1 | 72 | 119 |
| | | 1903 | 2 | 72 | 115 |
| Louisville, Miss. | American Creo. Wks. | 1912 | 1 | 108 | 172 |
| Argenta, Ark. | Ayer & Lord Tie Co. | 1907 | 4 | 74 | 132 |
| Texarkana, Ark. | Int. Creo. & Con. Co. | ...... | 1 | 114 | 165 |
| | | 1902 | 1 | 72 | 125 |
| Beaumont, Tex. | Int. Creo. & Con. Co. | 1892 | ..... | ....... | ....... |
| | | 1897 | 1 | 108 | 140 |
| Denison, Tex. | Mo. Kan. & Tex. Ry. Co. of Texas | 1909 | 4 | 72 | 108 |
| Texarkana, Tex. | Nat. Lum. & Creo. Co. | 1910 | 2 | 84 | 132 |
| Houston, Tex. | Nat. Lum. & Creo. Co. | 1912 | 4 | 72 | 120 |
| Houston, Tex. | Tex. & N. O. R. R. Co. | 1890 | 5 | 72 | 112 |
| Somerville, Tex. | A., T. & S. F. R. R. | 1906 | 5 | 74 | 132 |
| Hugo, Okla. | American Creo. Co. | 1907 | 2 | 84 | 134 |

CENTRAL STATES

| Location of plant | Managing company | Year built | No. of retorts | Diam. retorts (in.) | Length retorts (feet) |
|---|---|---|---|---|---|
| Toledo, Ohio......... | Federal Creo. Co............... | 1909 | 3 | 84 | 134 |
| Toledo, Ohio......... | Jennison-Wright Co............. | 1910 | 2 | 72 | 130 |
| Orrville, Ohio......... | Ohio Wood Pres. Co............ | 1912 | 1 | 84 | 132 |
| Cincinnati, Ohio....... | Comp. Wd. Pres. Co............ | 1909 | 1 | 72 | 76 |
| Indianapolis, Ind...... | Republic Creo. Co.............. | 1903 | 1 | 74 | 130 |
| Shirley, Ind........... | American Creo. Co............. | 1905 | 2 | 84 | 134 |
| Terre Haute, Ind...... | Indiana Zinc-Creo. Co.......... | 1904 | 2 | 72 | 120 |
| Terre Haute, Ind...... | Chicago Creosoting Co.......... | 1912 | 2 | 132 | 20 |
| Bloomington, Ind..... | Indiana Creosoting Co.......... | 1907 | 1 | 84 | 134 |
| Columbus, Ind........ | Indianapolis, Columbia & Southern Trac. Co. | 1909 | 1 | 72 | 45 |
| Evansville, Ind........ | Indiana Tie Co................. | 1907 | 2 | 72 | 110 |
| Waukegan, Ill ........ | Chicago Creosoting Co.......... | 1907 | 2 | 72 | 134 |
| Carbondale, Ill....... | Ayer & Lord Tie Co............ | ...... | 4 | 72 | 122 |
| | | 1902 | 4 | 74 | 132 |
| Marion, Ill........... | American Creo. Co............. | 1907 | 2 | 84 | 134 |
| Springfield, Ill........ | American Creo. Co............. | ...... | ...... | ...... | ...... |
| Madison, Ill.......... | Kettle River Co................ | 1909 | 4 | 84 | 135 |
| Galesburg, Ill....... . | C., B. & Q. R. R............... | 1907 | 5 | 74 | 132 |
| Mt. Vernon, Ill.. .... | T. J. Moss Tie Co............. | ...... | 1 | 74 | 132 |
| | | 1899 | 1 | 72 | 117 |
| Metropolis, Ill... | Joyce-Watkins Co.............. | 1914 | 1 | 72 | 132 |
| Joppa, Ill............. | Indiana Tie Co. ............. | 1909 | 2 | 72 | 110 |
| Bay City, Mich....... | Michigan Pipe Co.............. | 1893 | 1 | 72 | 42 |
| Escanaba, Mich....... | Chi. & N. W. Ry. Co........... | 1903 | 3 | 72 | 112 |
| Minneapolis, Minn.... | Republic Creosoting Co......... | 1905 | 2 | 74 | 130 |
| Sandstone, Minn...... | Kettle River Co................ | 1904 | 2 | 72 | 120 |
| Brainerd, Minn....... | Nor. Pac. Ry.................. | 1907 | 2 | 84 | 134 |
| Springfield, Mo....... | American Creo. Co............. | 1907 | 2 | 84 | 134 |
| Kansas City, Mo...... | American Creo. Co............. | 1907 | 2 | 84 | 134 |
| Topeka, Kansas....... | Union Pacific R. R............. | 1909 | 2 | 73 | 117 |

ROCKY MOUNTAIN AND PACIFIC STATES

| Location of plant | Managing company | Year built | No. of retorts | Diam. retorts (in.) | Length retorts (feet) |
|---|---|---|---|---|---|
| Somers, Mont. | Great Northern Ry. Co. | 1901 | 4 | 72 | 110 |
| Paradise, Mont. | Nor. Pac. Ry. Co. | 1907 | 2 | 84 | 134 |
| Butte, Mont. | Anaconda Cop. Min. Co. | 1910 | 1 | 72 | 43 |
| Sheridan, Wyo. | C., B. & Q. R. R. Co. | 1899 | 2 | 74 | 132 |
| Laramie, Wyo. | Union Pacific R. R. Co. | 1903 | 2 | 73 | 117 |
| Kellogg, Idaho | Bunker Hill and Sullivan Mining Co. | 1908 | 1 | 84 | 10 |
| Tacoma, Wash. | St. P. & Tacoma Lum. Co. | 1912 | 1 | 84 | 130 |
| Yardley, Wash. | Western Wd. Pres. Co. | 1912 | 1 | 84 | 65 |
| | | | 1 | 84 | 117 |
| Lowell, Wash. | Puget Sd. Wd. Pres. Co. | | 1 | 72 | 83 |
| | | 1895 | 1 | 72 | 52 |
| Seattle, Wash. | J. M. Colman Co. | 1912 | ..... | ...... | ...... |
| | | 1884 | 3 | 75 | 120 |
| Eagle Harbor, Wash. | Pacific Creosoting Co. | 1906 | 8 | 73 | 125 |
| Wyeth, Ore. | Oregon-Washington R. R. and Nav. Co. | 1904 | 4 | 72 | 114 |
| St. Helens, Ore. | St. Helens Creo. Co. | 1912 | 2 | 84 | 136 |
| Latham, Ore. | Southern Pac. R. R. | 1893 | 2 | 72 | 112 |
| Bulrington (near Portland) Ore. | Columbia Creo. Co. | 1912 | 1 | 72 | 65 |
| Alamogordo, N. Mex. | El. Paso & S.W.R.R. Co. | 19C2 | 2 | 72 | 106 |
| Albuquerque, N. Mex. | A. T. & S. F. Ry. Co. | 1908 | 2 | 74 | 132 |
| Oakland, Cal. | So. Pacific Ry. | | 1 | 72 | 108 |
| | | 1889 | 1 | 72 | 138 |
| Los Angeles, Cal. | So. Pacific Ry. | 1907 | 2 | 72 | 112 |
| San Pedro, Cal. | S. P. L. A. & S. L. R. R. | 1908 | 2 | 72 | 117 |

OPEN-TANK PLANTS

| Location of plant | Managing company | Year built |
|---|---|---|
| Lowell, Mass. | Otis Allen & Son | 1848 |
| Portsmouth, N. H. | Otis Allen & Son | 1875 |
| Ninticoke, Pa. | Del. Lack. & West. R.R. Coal Mining Dept. | 1907 |
| New Philadelphia, Pa. | Phila. and Reading Coal and Iron Co. | 1908 |
| New Orleans, La. | Reeves Co. | 1910 |
| Keokuk, Iowa | U. S. Wood Pres. Plant | 1908 |
| Milan, Ill. | U. S. Wood Pres. Plant | 1908 |
| Stillwater, Minn. | U. S. Wood Pres. Plant | 1908 |
| Fountain City, Wis. | U. S. Wood Pres. Plant | 1908 |
| Cleveland, Ohio | City of Cleveland | 1909 |
| Lead, S. Dak. | Homestake Mining Co. | 1908 |
| Portland, Ore. | Carbolineum W. P. Co. | 1910 |
| Lowell, Wash. | Puget Sound W. P. Co. | 1895 |
| Butte, Mont. | Anaconda Cop. Min. Co. | 1909 |
| Fresno, Cal. | San Joaquin Light and Power Co. | 1910 |
| San Miguel, Cal. | San Joaquin Light and Power Co. | 1910 |
| Oakland, Cal. | So. Pac. Ry. Co. | 1899 |
| Newark, N. J. | Public Service Corporation | 1906 |

## LIST OF "FIREPROOFING" PLANTS IN THE UNITED STATES

New York, N. Y. . . . . . . . . . . Standard Wood Treating Company.
New York, N. Y. . . . . . . . . . . Electric Fireproofing Company.

## THE AMOUNT OF WOOD PRESERVATIVES USED IN THE UNITED STATES

Creosote and zinc chloride are by far the preservatives consumed in largest quantities in the United States for preserving timber. About 3,000,000 gallons of other preservatives such as crude oil, carbolineum, and other varieties of preservatives derived from coal-tar were used in 1912. In addition, copper sulphate, mercuric chloride, and aluminum sulphate were also used, the exact amounts being unknown. The consumption of creosote and zinc chloride for preserving wood is shown in Table 38.

TABLE 38.—SHE APPROXIMATE AMOUNT OF CREOSOTE AND ZINC CHLORIDE CONSUMED IN THE UNITED STATES[1]

| Years | Creosote (gallons) | | | Zinc chloride (pounds); all domestic |
|---|---|---|---|---|
| | Domestic | Foreign | Total | |
| 1908 | 17,360,000 | 38,640,000 | 56,000,000 | 19,000,000 |
| 1909 | 13,862,000 | 37,569,000 | 51,431,000 | 16,215,000 |
| 1910 | 18,184,000 | 45,082,000 | 63,266,000 | 16,803,000 |
| 1911 | 21,511,000 | 51,517,000 | 73,027,000 | 16,360,000 |
| 1912 | 31,136,000 | 52,531,000 | 83,666,000 | 20,752,000 |

(Over 100,000,000 gallons of cresote reported used in 1913)

## AMOUNT OF TIMBER TREATED IN THE UNITED STATES

The amount of timber treated annually in the United States is shown in Table 39.

In addition to the amount shown in Table 39, a considerable amount of wood was treated with other preservatives such as carbolineum, crude oil, and various coal-tar products sold under a variety of trade names, but the exact amount of which is unknown.

[1] American Wood Preservers' Association Proceedings, 1913.

TABLE 39.—THE AMOUNT OF TIMBER TREATED IN THE UNITED STATES[1]

| Preservatives | Year | Cross-ties, cubic feet | Piling, cubic feet | Poles, cubic feet | Paving blocks, cubic feet | Construction timbers, cubic feet | Cross-arms, cubic feet | Lumber and miscellaneous, cubic feet | Total material treated each year, cubic feet |
|---|---|---|---|---|---|---|---|---|---|
| Creosote | 1907[A] | 17,252,622 | 4,423,611 | D | 2,874,560 | 1,687,450 | 238,742 | 4,561,327 | 31,038,312 |
| | 1908[A] | 28,861,260 | 6,059,919 | D | 1,260,020 | 2,657,398 | 480,640 | 6,065,717 | 45,384,054 |
| | 1909[B] | 29,830,080 | 4,421,726 | 659,664 | 2,994,290 | 4,902,311 | 41,764 | 417,787 | 43,367,622 |
| | 1910[B] | 44,525,229 | 5,219,254 | 255,597 | 4,692,543 | 7,801,272 | 88,069 | 2,687,713 | 65,269,587 |
| | 1911[B] | 49,532,163 | 4,937,303 | 106,213 | 10,145,724 | 7,417,105 | 71,961 | 2,499,995 | 74,710,534 |
| | 1912[B] | 57,461,515 | 7,624,939 | 1,169,981 | 7,091,058 | 6,892,493 | 1,643,128 | 2,481,195 | 84,724,909 |
| Zinc chloride | 1907[A] | 29,594,295 | D | D | D | 352,886 | D | 74,564 | 29,994,745 |
| | 1908[A] | 25,920,690 | D | D | D | 640,606 | D | 95,900 | 20,657,196 |
| | 1909[B] | 24,153,162 | D | D | D | 320,891 | D | 2,333 | 24,476,386 |
| | 1910[B] | 27,587,583 | D | D | D | 541,514 | D | 71,060 | 28,200,157 |
| | 1911[B] | 28,337,883 | D | D | D | 1,043,851 | D | 119,932 | 29,501,655 |
| | 1912[B] | 28,532,874 | D | 18,246 | D | 259,972 | D | 20,092 | 28,831,184 |
| Zinc creosote | 1907[A] | 7,037,010 | 152,541 | D | D | D | D | 5,691 | 7,195,242 |
| | 1908[A] | 9,781,590 | 426,610 | D | D | 95,700 | D | 35,858 | 10,339,758 |
| | 1909[B] | 8,095,794 | D | D | D | 62,918 | D | 43,699 | 8,202,411 |
| | 1910[B] | 6,354,219 | 38,392 | D | D | 181,143 | D | 30,646 | 6,604,440 |
| | 1911[B] | 7,312,374 | C | D | D | C | D | C | 7,312,374 |
| | 1912[B] | 8,214,303 | 97,874 | D | D | 560,613 | D | 99,367 | 8,972,157 |
| All preservatives | 1907[A] | 53,883,827 | 4,576,152 | D | 2,874,560 | 2,013,330 | D | 4,641,582 | 68,228,299 |
| | 1908[A] | 64,563,540 | 6,486,529 | D | 1,260,020 | 3,393,704 | 480,640 | 6,197,475 | 82,381,908 |
| | 1909[B] | 62,079,036 | 4,421,726 | 659,664 | 2,994,290 | 5,286,120 | 41,764 | 463,819 | 75,946,419 |
| | 1910[B] | 78,467,031 | 5,257,646 | 255,597 | 4,692,453 | 8,523,929 | 88,069 | 2,789,419 | 100,074,144 |
| | 1911[B] | 85,182,420 | 4,937,363 | 106,213 | 10,145,724 | 8,460,950 | 71,961 | 2,619,920 | 111,524,563 |
| | 1912[B] | 97,183,009 | 7,737,035 | 1,188,579 | 7,397,095 | 7,793,524 | 1,643,128 | 2,988,686 | 125,931,056 |

NOTE.—A. Figures furnished by the Wood Preservers' Association.
B. Figures furnished by the United States Forest Service.
C. Figures, if used, would reveal identity of reporting firms.
D. No statistics.

Converting Factors

To obtain the number of cross-ties, divide figures shown by 3.
To obtain the number of lineal feet of piling, divide the figures shown by 0.6763
To obtain the number of lineal feet of poles, divide the figures shown by 0.5868
To obtain the number of square yards of paving blocks, divide the figures shown by 2.625.
To obtain the number of board feet of construction timbers, divide the figures shown by 0.0833.
To obtain the number of cross-arms, divide the figures shown by 0.6198.
To obtain the number of board feet of lumber and miscellaneous material, divide the figures shown by 0.0833.

[1] American Wood Preservers' Association Proceedings, 1913.

About 4,000,000 feet of lumber are also given a "fireproof" treatment each year.

### LIST OF COMPANIES IN THE UNITED STATES EQUIPPED TO BUILD WOOD-PRESERVING PLANTS

| | |
|---|---|
| Allis-Chalmers Co | Milwaukee, Wis. |
| Basshor T. C. Co | Baltimore, Md. |
| Bovaird & Seyfaud Mfg. Co | Bradford, Pa. |
| Casey & Hedges | Chattanooga, Tenn. |
| Chicago Bridge & Iron Co | Chicago, Ill. |
| Coeur d'Alene Iron Works | Wallace, Idaho. |
| Cole, R. D | Newan, Ga. |
| Erie Heating Co | Chicago, Ill. |
| Fairbanks Morse Co | St. Paul, Minn. |
| Graves (Wm.)Tank Works | East Chicago, Ind. |
| Gravier Tank Works | Galveston, Tex. |
| Jacobs (S.) & Sons | Birmingham, Ala. |
| Lockett (A.M.) & Co | New Orleans, La. |
| Logan Iron Works | Brooklyn, N. Y. |
| Manitowoc Engineering Works | Manitowoc, Wis. |
| Mine-Smelter Supply Co | Denver, Colo. |
| Mohr (John) & Sons | Chicago, Ill. |
| Moran Bros | Seattle, Wash. |
| Morris Sherman Mfg. Co | Chattanooga, Tenn. |
| National Boiler & Sheet Iron Works | Indianapolis, Ind. |
| Payne & Joubert | New Orleans, La. |
| Petroleum Iron Works | Sharon, Pa. |
| Power & Mining Machinery Co | Milwaukee, Wis. |
| Reeves Bros. Co | Alliance, Ohio. |
| Struther-Wells Co | Warren, Pa. |
| Union Iron Works | San Francisco, Cal. |
| Vogt (Henry) | Louisville, Ky. |
| Williamette Iron & Steel Works | Portland, Ore. |

**Specifications for the Analysis of Creosote.**—A number of specifications for analyzing creosote oil have been proposed and are in force. Perhaps the best known and the one in most extended use is that adopted by the American Railway Engineering Association, which reads as follows:

### SPECIFICATIONS FOR ANALYSIS OF CREOSOTE OIL APPROVED BY THE AMERICAN RAILWAY ENGINEERING ASSOCIATION

1. The sample taken for analysis shall be strictly average of the whole bulk of oil to be tested. The oil shall be completely

liquefied and well mixed before samples are taken. Whenever possible a drip sample of not less than 2 gallons shall be taken commencing after the oil has started to run freely. When this cannot be done, as for instance, in large storage tanks, samples shall be taken from various depths in the tank by means of a tube or bottle, the number of samples depending on local conditions.

For taking samples during the process of treatment a sample of the oil shall be taken from the storage tank about 1 foot from the bottom of the tank before the cylinder is filled, and, where possible, a sample directly from the cylinder during the process of treatment. For this purpose a thermometer well may be used.

The sample to be analyzed shall be thoroughly liquefied by heating until no crystals adhere to a glass stirring rod, and also well shaken, after which one-half shall be taken for analysis and the balance reserved as check test.

2. The apparatus for distilling the creosote shall consist of a stoppered glass retort similar to that shown in diagram having a capacity as nearly as can be obtained of 8 ounces up to the bend of the neck when the bottom of the retort and the mouth of the off-take are in the same plane. A nitrogen filled mercury thermometer of good standard make, divided into full degrees Centigrade, shall be used in connection therewith. In order to insure uniform results for comparative purposes, the length of the thermometer bulb shall be one-half (1/2) inch; but in no case shall a thermometer with a long bulb be used. The bulb of the retort and at least two (2) in. of the neck shall be and remain covered with a shield of heavy asbestos paper, shaped as shown in diagram, during the entire process of distillation, so as to prevent heat radiation, and between the bottom of the retort and the flame of the lamp or burner two sheets of wire gauze, each 20-mesh fine, and at least 6 inches square, shall be placed.

The flame shall be protected against air currents. An ordinary tin can, from which a portion of the bottom and all of the top have been removed, placed on a support attached to the burner, as shown in diagram, will answer the purpose.

3. Before beginning the distillation the retort shall be carefully weighed and exactly 100 grams of oil placed therein, the same being weighed in the retort. The thermometer shall be inserted in the retort with the lower end of the bulb

1/2 inch from the surface of the oil and the condensing tube attached to the retort by a tight cork joint. The distance between the bulb of the thermometer and the end of the condensing tube shall not be less than 20 nor more than 24 inches, and during the progress of the distillation the thermometer shall remain in the position originally placed.

The distillate shall be collected in weighed bottles and all fractions determined by weight. Reports shall be made on the following fractions:

| | |
|---|---|
| 0 to 170° C. | 235 to 270° C. |
| 170 to 200° C. | 270 to 315° C. |
| 200 to 210° C. | 315 to 355° C. |
| 210 to 235° C. | Residue above 355° C. |

Reports shall be made on individual fractions. In making such reports it is to be distinctly understood that these fractions do not necessarily refer to individual compounds. In other words, the fraction between 210 and 235° will not necessarily be all naphthalene, but will probably contain a number of other compounds.

The distillation shall be a continuous one, and should require about 45 minutes.

When any measurable quantity of water is present in the oil the distillation shall be stopped, the oil separated from the water and returned to the retort, when the distillation shall be recommenced and the previous readings discarded. In obtaining water-free oil, it is desirable to free about 300 to 600 c.c. of the oil by using a large retort and using 100 grams of the water-free oil for the final distillation. In the final report as to fractions, a correction shall be made of the amount of water remaining, so that the report may be made on the basis of dry oil.

4. In order to determine the specific gravity of any oil, simply heat the oil in a water bath until it is completely liquid. A glass stirring rod dipped into the liquid should show no solid particle on the rod when the same is withdrawn from the oil. When completely liquid, it should be stirred thoroughly and the hydrometer cylinder filled, which has previously been warmed. Insert a specific gravity hydrometer of good make, taking care that the hydrometer does not touch the sides or bottom of the cylinder when the reading is taken. This reading should preferably be taken when the oil is at 38° C. (100° F.), because

at this temperature almost all oils are completely fluid. Where contract requirements specify a specific gravity at a different temperature, such gravity is obtained by multiplying 0.0008 by the number of degrees Centigrade, or 0.00044 by the number of degrees Fahrenheit, the oil is found to be above the temperature required by the contract, and adding the product to the observed gravity.

If it is desired to make further chemical analysis for the determination of the low-boiling tar acids and the naphthalene, the following method is recommended, tentatively:

"For the determination of low-boiling tar acids, the fractions should be placed in a separating funnel, to which should be added about 30 c.c. of the 15 percent hot sodium hydroxide solution, vigorously shaken, and allowed to stand until the dissolved phenols separate out and may be drawn off, after which repeat with successive sodium hydroxide solutions 20 c.c. each time until no phenols are left (the sodium solution comes off clear). The phenols so obtained should be separated by the addition of a 25 percent sulphuric acid, slowly stirred in. When this reaction is complete, the phenols so obtained should be decanted and weighed."

The Committee on Wood Preservation of the National Electric Light Association was not entirely satisfied with the above specifications for analysis and drew up a set of its own.[1] In the opinion of this committee the above specification does not fully meet present requirements because "it is generally admitted by chemists that the retort is an antiquated piece of apparatus," and furthermore the test is not sufficiently stringent to detect adulterations. The specification for analysis which this committee recommended reads as follows:

### ANALYSIS SPECIFICATIONS (NATIONAL ELECTRIC LIGHT ASSOCIATION)

#### General

"The apparatus employed in making the distillation and other tests required under these specifications shall conform in general to that shown on drawings Fig 26 (Fig. No. *a*) and Fig. 27 attached to and forming a part of these specifications, except that a five percent (5%) variation from the dimensions given is

[1] Report of Committee on Preservative Treatment of Poles and Cross Arms, National Electric Light Association, 1911.

allowed. The distilling apparatus must be assembled as in drawing Fig 28. As further defining the requirements in this respect, the following description of certain parts and manner of assembling is given:

(*a*) *Flask.*—The flask required is a Lunge side neck distilling flask, provided with a trap (Fig. 26), and having a tubular side neck thirty centimeters (30 cm.) long placed close to the bulb. The flask must have a capacity of three hundred cubic

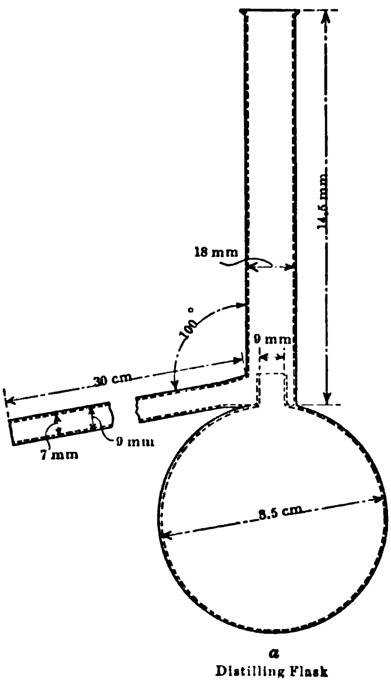



Fig. 26.

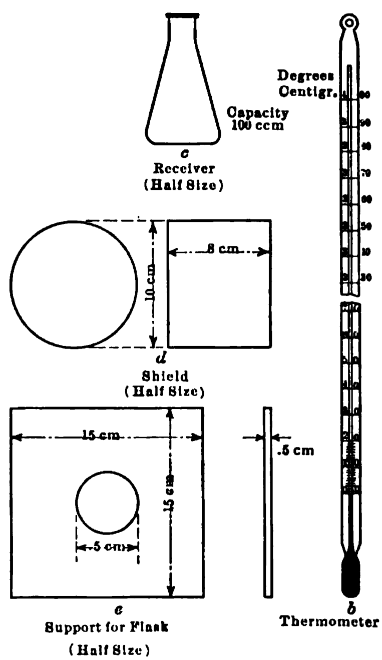



Fig. 27.

centimeters (300 c.c.) when filled to a height equal to its maximum horizontal diameter.

(*b*) *Thermometer.*—The thermometer must be made of Jena glass and be nitrogen filled and graduated at intervals of one millimeter (1 mm.) in single degrees Centigrade, the scale reading to plus four hundred degrees Centigrade (+ 400° C.).

(*c*) *Receivers.*—The glass receivers may be of any convenient size and shape; the flask shown on drawing No. 114 is, however, recommended.

(*d*) *Shield.*—A shield ten centimeters (10 cm.) in diameter and eight centimeters (8 cm.) high, made of asbestos, must be provided (Fig. 27).

(*e*) *Support for Flask.*—The flask must rest on an asbestos board one-half centimeter (0.5 cm.) in thickness by fifteen centimeters (15 cm.) in diameter, a hole five centimeters (5 cm.) in diameter being cut in the center of the board. The board shall rest on a ring stand (Fig. 27).

### ASSEMBLING APPARATUS

The apparatus must be assembled as shown in figure No. 28. The thermometer passes through a cork in the top of the

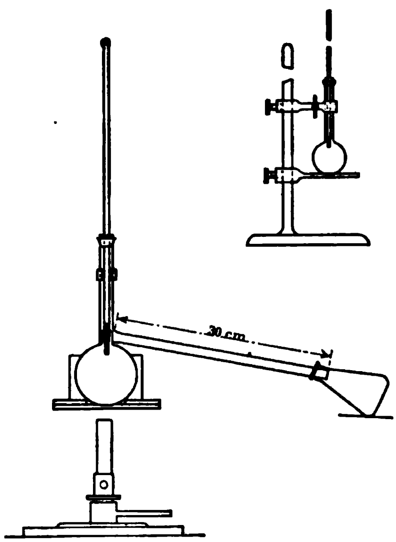



FIG. 28.

flask and is so placed that the top of the bulb of the thermometer is on a line with the bottom of the tubular outlet. The asbestos shield is placed around the bulb of the flask and the flask mounted on the asbestos board supported on the ring stand as shown on drawing Fig. 28.

### Distillation Test

Two hundred grams of the oil shall be used in the analysis, this amount being weighed on a balance sensitive to one milligram (1 mg.), in the following manner:

The flask is first placed on the pan of the balance and weighed, and the weight recorded. Without removing the flask, a two hundred (200) gram weight is placed on the opposite pan of the balance and a sufficient quantity of the oil dropped into the flask through a long stem funnel to bring the pans into equilibrium. The flask is then removed from the balance and set up as in drawing Fig. 28. Care must be taken that the cork stopper carrying the thermometer fits tightly into place. The flask should be heated, preferably by a Bunsen or other standard form of gas burner. The distillation shall be continuous and at such a rate that two (2) drops of oil per second (5 c.c. per minute) leaves the end of the tubular after the thermometer registers two hundred and five degrees Centigrade (205° C.), or after all of the water has been driven off. The percentage weights of the following fractions shall be recorded:

To 205° C.
To 235° C.
To 245° C.
To 270° C.
To 315° C.
To 360° C.

#### DETERMINATION OF FREE CARBON

The apparatus required is as follows:

Knorr Condenser.
Knorr Flask.
C. S. & S. No. 575 Filter Papers, 15 cm. diameter.
Wire for supporting filter papers.

Ten grams of the oil should be weighed into a small beaker and digested with C. P. toluol on a steam bath. A cylindrical filter cup is prepared by folding two of the papers around a rod about five-eights of an inch (5/8″) in diameter. The inner paper should be cut to fourteen centimeters (14 cm.) diameter. Prior to using the filter papers, they should have been extracted with benzol to render them fat free. The filter cup is dried at one hundred (100) to one hundred and ten (110) degrees Centigrade and weighed in a weighing bottle.

The contents of the beaker are now decanted through the filter cup, and the beaker washed with hot toluol, passing all washings through the cup. The filtrate should be passed through

the filter a second time, the residue washed two or three times with hot C. P. benzol and transferred to the extraction apparatus, in which C. P. benzol is used as the solvent, which solvent is vaporized by means of a steam or water bath. The extraction is continued until the filtrate is colorless. The filter cup is then removed, dried and weighed in the weighing bottle. C. P. benzol followed by chloroform may be used instead of C. P. toluol followed by C. P. benzol.

**Precautions.**—In removing filter paper from the extraction apparatus see that no particles of mercury find their way into the precipitate. To prevent splashing, the filter paper should be elevated as near to the outlet of the condenser as possible. A good precaution is to cover the top of the filter cup with a round cap of filter paper.

**Sulphonation Test**

Ten cubic centimeters (10 c.c.) of the total distillate to three hundred and fifteen degrees Centigrade (315° C.) are placed in a flask and warmed with four (4) to five (5) volumes of concentrated sulphuric acid to sixty degrees Centigrade (60° C.) and the whole transferred to a graduated separatory funnel. The flask is rinsed three times with small quantities of concentrated sulphuric acid and the rinsings added to the contents of the funnel, which is then stoppered and shaken, cautiously at first, afterward vigorously, for at least fifteen (15) minutes and allowed to stand over night. The acid is then carefully drawn down into the graduated portion of the funnel to within two cubic centimeters (2 c.c.) of where the unsulphonated residue shows. If no unsulphonated residue is visible the acid should be drawn down to two cubic centimeters (2 c.c.). In either case the test should be carried further as follows: Add about twenty cubic centimeters (20 c.c.) of water and allow to stand for 1/2 hour. Then draw off the water as close as possible without drawing off any supernatant oil or emulsion, and ten cubic centimeters (10 c.c.) of strong sulphuric acid and allow to stand for from fifteen to twenty (15 to 20) minutes. Any unsulphonated residue will now separate out clear and give a distinct reading. If under two-tenths of a cubic centimeter (0.2 c.c.) it should be drawn down into the narrow part of the funnel to just above the stop-cock, where it can be estimated to one one-hundredth of a cubic centimeter (0.01 c.c.) The volume of residue thus obtained is calculated to the original oil."

## DETERMINATION OF TAR ACIDS

One hundred cubic centimeters (100 c.c.) of the total distillate to three hundred and fifteen degrees (315° C.), to which forty cubic centimeters (40 c.c.) of a solution of sodium hydroxide having a specific gravity of one and fifteen hundredths (1.15) is added, is warmed slightly and placed in a separatory funnel. The mixture is vigorously shaken, allowed to stand until the oil and soda solutions separate and the soda solution containing most of the tar acids drawn off. A second and third extraction is then made in the same manner, using thirty (30) and twenty (20) cubic centimeters of the soda solution, respectively. The three alkaline extracts are united in a two hundred cubic centimeter (200 c.c.) graduated cylinder and acidified with dilute sulphuric acid. The mixture is then allowed to cool and the volume of tar acids noted. The results shown should be calculated to the original oil.

## COKE TEST

In making the coke determination, hard glass bulbs are to be used. The test is to be carried out as follows:

Warm the bulb slightly to drive off all moisture, cool in a desiccator and weigh. Again heat the bulb by placing it momentarily in an open Bunsen flame and place the tubular side neck underneath the surface of the oil to be tested and allow the bulb to cool until sufficient oil is sucked in to fill the bulb about two-thirds full. Any globules of oil sticking to the inside of the tubular should be drawn into the bulb by shaking or expelled by slightly heating it, and the outer surface should be carefully wiped off and the bulb re-weighed. This procedure will give about one gram of oil. Cut a strip of thin asbestos paper about one-quarter inch wide and about 1 inch long, place it around the neck of the bulb and catch the two free ends close up to the neck with a pair of crucible tongs. The oil should then be distilled off as in making an ordinary oil distillation, starting with a very low flame and conducting the distillation as fast as can be maintained without spurting. When oil ceases to come over, the heat should be increased until the highest temperature of the Bunsen flame is attained, the whole bulb being heated red hot until evolution of gas ceases and any carbon sticking to the outside of the tubular is completely burned off. The bulb should then be cooled in a desiccator and weighed and the percentage of coke residue calculated to water-free oil.

Still[1] more refined specifications for analyzing creosote oil, especially as regards the method of distillation and sulphonation residues, are those in use by the U. S. Forest Service. In the author's opinion these tests are much more exact than either of the two just given. They are, however, more troublesome and hence expensive to make, but where accuracy is desired, their use is recommended.

## Specifications for Analyzing Creosote Used by the U. S. Forest Service

(*Note.*—All temperatures referred to in the following are on the centigrade scale.)

### SPECIFIC GRAVITY OF THE WHOLE OIL

"The perfectly liquefied oil is poured into a hydrometer cylinder, and, at a temperature of 60°, the specific gravity is read with hydrometer standardized against water at 60°.

The somewhat prevalent method of determining specific gravity with a hydrometer standardized at 15° and then calculating the results from the temperature of the determination back to 15° is roundabout and involves the expression of the specific gravity of creosote in the liquid condition at a temperature at which the oil does not exist as a liquid. The method is illogical and open to inaccuracies. With very rare exceptions creosotes are all liquid at 60°, and if the weight of a unit volume of the oil at 60° is compared with the weight of a unit volume of water at 60°, a true specific gravity is obtained. . . .

### FRACTIONAL DISTILLATION

The Hempel distilling flask of resistance glass is employed. The empty flask is tared, 250 grams of melted, well-shaken oil introduced, the platinum-wire plug and the glass beads put in place, and a second weight taken. The thermometer is then inserted in the flask, so that the first emergent reading is 200°. The flask is supported on an asbestos board with a slightly irregular opening of very nearly the largest diameter of the flask. A condensing tube is employed and the fractions are collected in

[1] Circular 206, United States Forest Service.

taied flasks. The distillation is run at the rate of 1 drop per second, and fractions collected between the following temperatures: Up to 170°, 170°–205°, 205°–225°, 225°–235°, 235°–245°, 245°–255°, 255°–285°, 285°–295°, 295°–305°, 305°–320°, and if feasible, 320°–360°.

The characters of the fractions and their weights are recorded and the results plotted as a curve, in which the ordinates are percentages by weight and the abscissæ temperatures. . . . When the distillation has reached the 225° point, an asbestos-board box should be placed around the distilling flask, to cover the bulb, but leave the Hempel column exposed. Drafts upon the distilling apparatus must be avoided.

## INDEX OF REFRACTION

The indices of refraction of the different fı actions between 235° and 305° are determined at 60° in a refractometer with light compensation. The results are plotted with temperatures as abscissæ and indices of refraction as ordinates.

"**Index of Refraction.**—The index of refraction is the ratio between the sines of the angles of incidence and of refraction of light, expressed by the formula $\frac{n}{D} = \frac{\text{sine } I}{\text{sine } R}$, where $\frac{n}{D}$ means the index of refraction referred to sodium light, $I$ equals the angle of incidence, and $R$ the angle of refraction. The index of refraction varies with the temperature, but is constant for any given oil at a stated temperature. In making measurements of the index of refraction of the different fractions of a creosote distillation, it was necessary to make the measurements at 60°. The determinations were made with an Abbe refractometer provided with a light compensator. By means of this instrument the index of refraction may be read with great accuracy, and the measurement is one of the most exact which can be applied to such an oil.

"**Sulphonation Test.**—In contradistinction to the hydrocarbons of the paraffin series, those of the aromatic series react with concentrated sulphuric acid with marked ease. The products of this reaction, in which a sulpho group or groups replace hydrogen in the aromatic compound, are called sulphonic acids and the process is known as sulphonation. For example, the reaction with benzene would be $C_6H_6 + H_2SO_4 = C_6H_5SO_3H + H_2O$. The sulphonic acids are characterized by their solubility in water. If a fraction from the distillation of a creosote oil be treated under proper conditions with concentrated sulphuric acid, it will be converted into a mixture of sulphonic acids, which will readily dissolve in water. If, however, there are paraffin bodies present they will not be attacked to the same degree as

[1] The following explanation of the index of refraction and of the sulphonation test is taken from U. S. Forest Service Circular 112:

the aromatic hydrocarbons, and when the products of the sulphonation are treated with water the paraffin components will remain as a residual oil. In applying this test to creosote oils it has been found that the most information is obtained by using it on the higher boiling fractions."

*Specific Gravity.*—The specific gravities of the fractions between 235° and 305° are determined by means of specific-gravity bottles. These bottles are filled at 60° and the weights referred to water at the same temperature. The results are plotted as a curve in which the ordinates are specific gravities at 60° and the abscissæ temperatures.

*Sulphonation Tests.*[1]—Ten cubic centimeters of the fraction of creosote to be tested are measured into a Babcock milk bottle. To this is added 40 c.c. of 37 times normal acid, 10 c.c. at a time. The bottle with its contents is shaken for 2 minutes after each addition of 10 c.c. of acid. After all the acid has been added the bottle is kept at a constant temperature of from 98° to 100° C. for 1 hour, during which time it is shaken vigorously every 10 minutes. At the end of an hour the bottle is removed, cooled, and filled to the top of the graduation with ordinary sulphuric acid, and then whirled for 5 minutes in a Babcock separator. The unsulphonated residue is then read off from the graduations. The reading multiplied by 2 gives percent by volume directly. (Each graduation equals one two-hundredth of a cubic centimeter.)

In well-equipped chemical laboratories the usual steam-jacket ovens, capable of maintaining a temperature of from 98° to 100° C., will keep the reaction mixture of the sulphuric acid and creosote at the proper temperature. It frequently happens, however, that creosotes are analyzed in a laboratory equipped only for that purpose, and for such cases a special steam bath or oven can be made by any tinsmith at small cost. It is essential that the chamber be of sufficient size to completely contain (under the cover) the Babcock bottle; otherwise the exact dimensions of the steam bath are unimportant, and any two vessels of suitable dimensions, which are at hand or can most readily be obtained, may be utilized in its construction.

*Tar Acids.*—Fifty cubic centimeters of the creosote under analysis are measured at 60° into a small distilling flask by a pipette. The oil is distilled as completely as possible without breaking the distilling bulb, and the distillate is caught in a short-stemmed

[1] U. S. Forest Service Circular 191.

100. c.c. separating funnel. At the end of the distillation 25 c.c. of boiling hot 15 percent sodium hydroxide are added to the distillate and the mixture thoroughly shaken. The alkaline extract is then drawn off into a 100 c.c. cylinder and 25 c.c. more of hot sodium hydroxide added. After extracting with this second portion for 5 minutes, with frequent shaking, the solutions are allowed to separate and the alkaline extract added to the first portion in the cylinder. A third extraction is made with 15 c.c. of alkali. The total alkaline extract is cooled, acidified with sulphuric acid, thoroughly shaken, brought to 60°, and the volume of supernatant oil read off.

*Water.*—After weighing the first two fractions of a fractional distillation they are united in a small separatory funnel and any water which is present is separated from the oil and its amount accurately determined. If particular accuracy is required in the estimation of the water it may be done by the Marcusson xylol distillation method.[1]"

#### METHOD FOR DETERMINING THE AMOUNT OF MOISTURE IN CREOSOTE AND CREOSOTED WOOD

"The creosoted wood, in the form of borings, turnings, sawdust, or similar material, is quickly weighed and transferred to the 250 c.c. Erlenmeyer flask, and 75 c.c. of water-saturated xylol[2] added. The basin in which the flask is placed should be two-thirds full of melted paraffin or of some heavy lubricating oil such as cylinder oil. The bath is heated and the distillation continued until the distillate comes in clear drops. At the end of the distillation the condenser should be rinsed with the stream from a wash bottle containing xylol. After it has stood for a short time, the emulsion of water and xylol separates, giving two clear liquid layers. The mean of the readings at the top and bottom of the meniscus, between xylol and water, gives the volume of water, and the percentage of moisture in the wood is obtained by multiplying the water volume by 4. There are always small globules of water adhering to the sides of the graduate in the portion filled with xylol. These are readily

[1] Forest Service Circular 134, The Estimation of Moisture in Creosoted Wood, A. L. Dean.

[2] Water-saturated xylol is readily prepared by heating a mixture of water and xylol with frequent shakings and subsequently removing the water in a separatory funnel.

scrubbed down with a piece of rubber tube on the end of a piece of glass tubing, which is better for this purpose than the rod commonly used for a "policeman."

It is important that the distillation be carried on slowly to allow all the water in the wood to volatilize. The finer the wood particles, the more rapid may be the distillation. If rather coarse material is used, the distillation should not run faster than 1 drop per second.

The apparatus shown in Fig. 29 was devised for making large numbers of moisture estimations on creosoted wood. The

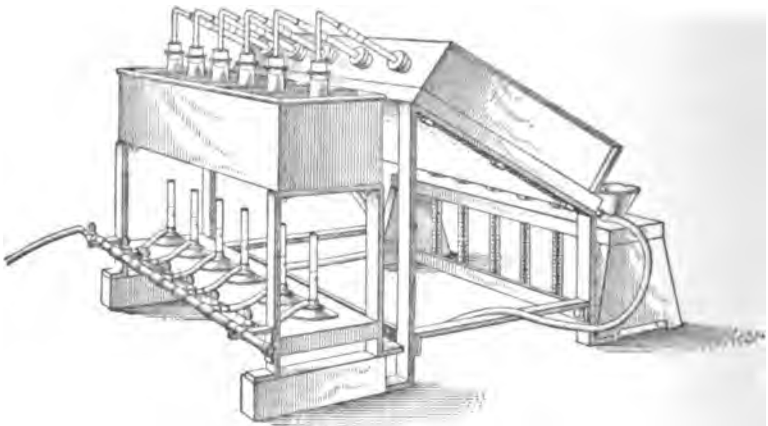


FIG. 29.—Apparatus for making several moisture determinations in creosoted wood.

compartments of the paraffin bath are larger than necessary for the 250 c.c. flasks, but the apparatus was designed so that larger flasks might be employed when considerable wood was to be used, for purposes of investigation, to obtain very accurate results.

Marcusson's method is well adapted to the estimation of water in creosote oils. The apparatus used for creosoted wood is satisfactory for creosote, except that a wire gauze should be substitute for the paraffin bath. The 250 cubic centimeter flask is weighed, 50 cubic centimeters of melted, well-shaken creosote introduced, and a second weight taken. Seventy-five cubic centimeters of water-saturated xylol are added and the mixture distilled until the water ceases to come off. The percentage of water is obtained by dividing the volume (cubic centimeters) of water in the distillate by the weight (grams) of creosote. The results are likely to run one or two-tenths of a percent too low.

**THE DURABILITY OF AMERICAN TIMBERS**

The durability of timber is so exceedingly variable that any general table is of value solely in securing an approximate idea of the durability of one wood as compared with another—and not as an index of what the wood will actually do under all conditions. For example, timber used in the South and exposed to the weather will decay quicker than the same timber placed under similar conditions in the North; timber cut from a given tree may be more durable than timber cut from the same kind of a tree which grew next to it; timber placed in one kind of soil may be far more durable than the same timber placed in another soil, etc. All of these variations have been discussed in the preceding chapters. Taking all of them into consideration and striking an average for common practice, Table 40 has been compiled. It naturally follows that these figures are of chief value in comparing the relative durability of one kind of untreated wood with another, and it is believed that most of them are approximately correct. As more authentic data is collected, it is quite likely that changes in the estimated durability will be necessary.

TABLE 40.—THE ESTIMATED DURABILITY OF UNTREATED WOOD IN CONTACT WITH THE SOIL

| *Class A.*—Very durable woods. (These woods will probably last more than 25 years in contact with the soil) | *Class B.*—Durable woods. (These woods willprobably last more than 10 years but less than 25 years in contact with the soil) | *Class C.*—Nondurable woods. (These woods will probably last less than 10 years in contact with the soil) |
|---|---|---|
| Black locust | Chestnut | Aspen |
| Northern white cedar | Southern white cedar | Ash |
| Western red cedar | Douglas fir | Beech |
| Cypress | Red gum (heart) | Birch |
| Mulberry | White oaks | Basswood |
| Osage orange | Longleaf pine | Balsam |
| Redwood | | Cottonwood |
| | | Elm |
| | | Red gum (sap) |
| | | Blue gum |
| | | Hemlock |
| | | Red oaks |
| | | Western yellow pine |
| | | Lodgepole pine |
| | | Loblolly pine |
| | | Sitka spruce |
| | | White spruce |
| | | Sycamore |
| | | Tamarack |
| | | Tupelo |

**List of U. S. Patents on Wood Preservation**

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Henry Aitken, Darroch, Falkirk, Scotland | Preserving timber. | 352,216 | Nov. 9, 1886 |
| Hugo Akerhielm, Chicago, Ill. | Improvement in compositions for preserving wood. | 185,058 | Dec. 5, 1876 |
| Augustus, Allen, Cass Co., Mich. | Improved method of preventing decay in the timbers of bridges, buildings, etc. | 106,647 | Aug. 23, 1870 |
| Edw. R. Andrews, New York, N. Y. | Composition for preserving wood. | 247,234 | Sept. 20, 1881 |
| W. C. Andrews, New York, N. Y. | Vulcanising wood. | 430,055 | June 10, 1890 |
| Philip F. Apfel, Seattle, Wash. and Ralph L. Earnest, Portland, Ore. | Protecting piles against worms, etc. | 883,507 | Mar. 31, 1908 |
| Oliver App, Blue Mound, Ill. | Improvement in compositions for preserving wood. | 219,377 | Sept. 9, 1879 |
| R. W. Archer, Corpus Christi, Tex. | Improvement in processes for preserving wood. | 153,515 | July 28, 1874 |
| McKenzie Arnn, Bristol, Va. | Composition for coloring and preserving wood. | 601,767 | Apr. 5, 1898 |
| McKenzie Arnn, Bristol, Va. | Wood preserving compound. | 633,778 | Sept. 26, 1890 |
| Chas. Arnoudts, Seattle, Wash. | Composition for preserving piles from teredo, etc. | 526,552 | Sept. 25, 1894 |
| Max Bachert, New York, N. Y. | Apparatus for saturating wood. | 666,915 | Jan. 29, 1901 |
| Max Bachert, New York, N. Y. & D. W. O'Neil, Newark, N. J. | Preserved wood and process of preparing same. | 602,713 | Apr. 19, 1898 |
| Thurman Bailey, Bridport, Vt. | Improvement in processes for preparing wood for roofing. | 125,251 | Apr. 2, 1872 |
| Jas. J. Barr, Slidell, La. | Automatic retort-cover. | 857,148 | June 18, 1907 |
| Jas. R. Bate, Cincinnati, Ohio. | Process of preserving wood. | 522,284 | July 3, 1894. |
| Frank Batter, Marshfield, Ore. | Apparatus for preserving piles. | 452,513 | May 19, 1891 |
| J. H. Bauer, Scranton, Pa. | Improvement in processes for treating sounding-boards. | 149,426 | Apr. 7, 1874 |
| S. Beer, New York, N. Y. | Improved process for seasoning and preserving wood. | 73,565 | Jan. 21, 1868 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Nane and address inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Andries Bevier, New York, N. Y. | Method of preserving wood. | 681,032 | Aug. 20, 1901 |
| V. W. Blanchard, Bridport, Vt. | Improved mode of preserving wood. | 94,704 | Sept. 14, 1869 |
| Guido Blenio, New York, N. Y. | Process for fireproofing wood. | 779,761 | Jan. 10, 1905 |
| A. T. Bleyley, Conception, Mo. | Improvement in processes for preserving burial cases, etc. | 175,329 | Mar. 28, 1876 |
| H. H. Blodgett, Omaha, Nebr. | Wood-preserving composition | 606,702 | July 5, 1898 |
| John B. Blythe, Bordeaux, France. | Treating railway-sleepers. | 313,912 | Mar. 17, 1885 |
| John B. Blythe, Bordeaux, France. | Apparatus for treating, seasoning and preserving timber. | 313,913 | Mar. 17, 1885 |
| John Borner, Rahway, N. J. | Apparatus for impregnating wood. | 703,522 | July 1, 1902 |
| S. B. Boulton, Cooped Hall, County of Hertford, England. | Treating timber with preservative fluids. | 247,602 | Sept. 27, 1881 |
| S. B. Boulton, London, Eng. | Method of preserving timber. | 360,947 | Apr. 12, 1887 |
| Edmond Bouvier, Pensacola, Fla. | Improvement in solutions for preserving timber. | 218,659 | Aug. 19, 1879 |
| Joachim Brenner, Gainfarn, Austria-Hungary. | Process of dyeing wood. | 755,993 | Mar. 29, 1904 |
| Jas. P. Bridge, Boston, Mass. | Improved compound for preserving wood, leather, etc. | 86,808 | Feb. 9, 1869 |
| Robert E. Bright, Grenada, Miss. | Apparatus for treating timber. | 887,583 | May 12, 1908 |
| H. R. Brinkerhoff, Oakpark, Ill. | Waterproofed wood and method of making same. | 686,582 | Nov. 12, 1901 |
| Albert Brisbane, New York, N. Y. | Improvement in processes for treating wood for paving and other purposes | 155,788 | Oct. 13, 1874 |
| Wm. Brisley, and Wm. S. Finch, Toronto, Canada | Composition for preserving wood. | 359,384 | Mar. 15, 1887 |
| Chas. Brown, Albemarle Co., Va. | Improved process of preserving timber from decay. | 83,758 | Nov. 3, 1868 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Saml. P. Brown, Washington, D. C. | Improvement in preserving wood. | 115,931 | June 13, 1871 |
| W. C. Bruson, Chicago, Ill. | Compound for preserving wood. | 251,346 | Dec. 27, 1881 |
| Walter Buehler, Minneapolis, Minn. | Preserving wood. | 899,237 | Sept. 22, 1908 |
| Walter Buehler, Minneapolis, Minn. | Preserving wood. | 899,480 | Sept. 22, 1908 |
| Wm. W. Bunnell, Thomasville, Nebr. | Compound for preserving wood. | 238,341 | Mar. 1, 1881 |
| Peter Grant Burns, St. Louis, Mo. | Wood-preserving apparatus. | 864,092 | Aug. 20, 1907 |
| Rudolph G. Burstenbinder, Hamburg, Germany | Preservation of wood. | 266,092 | Oct. 17, 1882 |
| Jas. J. Byers, Gulfport, Miss. | Wood saturating and coating apparatus. | 858,950 | July 2, 1907 |
| Saml. Cabot, Jr., Boston, Mass. | Improvement in processes for preserving wood. | 184,141 | Nov. 7, 1876 |
| Saml Cabot, Brookline, Mass. | Compound for bleaching and preserving wood. | 515,191 | Feb. 20, 1894 |
| Jas. Calkins, New York, N. Y. | Improvement in preserving wood. | 78,514 | June 2, 1868 |
| Jos. P. Card, St. Louis, Mo. | Preserving wood. | 254,274 | Feb. 28, 1882 |
| Jos. P. Card, St. Louis, Mo. | Process of preserving wood. | 317,440 | May 5, 1885 |
| J. P. Card, Chicago, Ill. | Solution for preserving wood. | 419,582 | Jan. 14, 1890 |
| Jos. B. Card, Chicago, Ill. | Method of preserving wood. | 815,404 | Mar. 20, 1906 |
| C. S. Chamberlain, Oakland, Cal. | Wood-preserving apparatus. | 621,774 | Mar. 21, 1899 |
| Octave Chanute, Kansas City, Mo. | Preserving timbered structures. | 430,068 | June 10, 1890 |
| Octave Chanute, Chicago, Ill. | Process of preserving wood. | 688,932 | Dec. 17, 1901 |
| S. B. Chapman, Abbeville, Ga. | Solution for preserving lumber. | 764,913 | July 12, 1904 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Sydney B. Chapman, Skyland, N. C. | Treated wood and process of producing the same. | 839,551 | Dec. 25, 1906 |
| Emile Chevigny | Composition of matter for painting and preserving wood. | 824,794 | July 3, 1906 |
| William B. Chisholm, Charleston, S. C. | Preservation of wood. | 802,680 | Oct. 24, 1905 |
| Chas. E. Clarke, Geo. Hadley, and J. C. Clifford, Buffalo, N. Y. | Improved mode of preserving wood. | 67,104 | July 23, 1867 |
| E. W. Clark, Hartford, Conn. | Improved solution for the treatment of wood. | 94,869 | Sept. 14, 1869 |
| Seth L. Cole, Brooklyn, N. Y. | Improvement in preserving wood. | 124,419 | Mar. 12, 1872 |
| Seth L. Cole, Brooklyn, N. Y. | Improvement in processes of preserving wood. | 124,420 | Mar. 12, 1872 |
| Edw. Z. Collings, Camden, N. J. | Apparatus for preserving wood. | 310,880 | Jan. 20, 1885 |
| Edw. Z. Collings, Camden, N. J. | Method of preserving wood. | 317,730 | May 12, 1885 |
| Jos. H Connelly, Allegheny, Pa. | Preserved wood. | 243,062 | June 21, 1881 |
| Silas Constant, Peekskill, N. Y. and John Smith, Brooklyn, N. Y. | Improvement in seasoning and preserving wood. | 65,545 | Mar. 17, 1867 |
| Silas Constant, Peekskill, and John Smith, Brooklyn, N. Y. | Improvement in seasoning and preserving wood. | 116,274 | June 27, 1871 |
| Geo. C. Cowles, Bay Mills, Mich. | Undressed lumber and process of preserving same. | 746,678 | Dec. 15, 1903 |
| E. L. Cowling, Boston, Mass. | Improvement in preserving wood. | 84,733 | Dec. 8, 1868 |
| C. M. Cresson, Philadelphia, Pa. | Improvement in preserving wood. | 79,554 | July 7, 1868 |
| C. M. Cresson, Philadelphia, Pa. | Improvement in seasoning and preserving wood. | 109,872 | Dec. 6, 1870 |
| C. M. Cresson, Philadelphia, Pa. | Improvement in seasoning and preserving wood. | 109,873 | Dec. 6, 1870 |
| Wm. Cross, Brisbane, Queensland. | Method of preserving timber. | 643,762 | Feb. 20, 1900 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| W. G. Curtis, and J. D. Isaacs, San Francisco, Cal. | Process of preserving timber. | 545,222 | Aug. 27, 1895 |
| W. G. Curtis, and J. D. Isaacs, San Francisco, Cal. | Process of preserving wood. | 11,515 | Dec. 3, 1895 |
| A. R. Davis, Cambridge, Mass. | Improved process of treating wood for covering walls. | 74,056 | Feb. 4, 1868 |
| Edw. Davis, Redondo, Cal. | Pliable-flange pile-casing. | 464,960 | Dec. 15, 1891 |
| J. C. Day, Hackettstown, N. J. | Improvement in seasoning and preserving wood. | 100,380 | Mar. 1, 1870 |
| J. A. Deghuee, New York, N. Y. | Method of preserving and waterproofing wood. | 802,739 | Oct. 24, 1905 |
| E. J. De Smedt, New York, N. Y. | Improved composition for preserving timber and wood. | 100,608 | Mar. 8, 1870 |
| B. H. Detwiler and S. G. Van Gilder, Williamsport Pa. | Improvement in preserving woods. | 111,045 | Jan. 17, 1871 |
| Fred Dixon, London, Eng. | Improvement in processes for treating wood. | 181,651 | Aug. 29,1876 |
| B. V. B. Dixon and J. P. Card, St. Louis, Mo. | Preserving wood. | 239,033 | Mar. 22, 1881 |
| John Dolbeer, San Francisco, Cal. | Apparatus for steaming piles. | 333,204 | Dec. 29, 1885 |
| H. C. Dorr, San Francisco, Cal. | Compound for preserving wood. | 293,955 | Feb. 19, 1884 |
| C. J. Doyle, Philadelphia, Pa. | Apparatus for preserving wood. | 645,793 | Mar. 20, 1900 |
| J. A. Draper, Shaftsbury, Vt. | Improvement in compounds for preserving wood. | 152,620 | June 30, 1874 |
| Wm. Dripps, Coatesville, Pa. | Improved process of restoring and preserving decaying railroad ties. | 96,405 | Nov. 2, 1869 |
| P. H. Dudley, New York, N. Y. | Apparatus for impregnating wood. | 381,682 | Apr. 24, 1888 |
| P. H. Dudley, New York, N. Y. | Preserving railway-ties. | 406,566 | July 9, 1889 |
| Firmin Dufouric, New York, N. Y. | Improvement in processes for preserving wood. | 150,841 | May, 12 1874 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| P. F. Dundon, San Francisco, Cal. | Timber-treating process. | 753,052 | Feb. 23, 1904 |
| Chas. J. Eames, New York, N. Y. | Improvement in processes for preserving wood. | 134,133 | Dec. 24, 1872 |
| Edw. Earle, Savannah, Ga. | Improvement in the mode of preserving timber. | 934 | Sept. 20, 1838 |
| H. F. Eckert, San Francisco, Cal. | Apparatus for preserving timber. | 509,724 | Nov. 28, 1893 |
| H. L. Eddy, Geneva, N. Y. | Improved method of preserving wood. | 53,217 | Mar. 13, 1866 |
| W. E. Everette, Tacoma, Wash. | Method of preserving wood. | 801,859 | Oct. 17, 1905 |
| L. S. Fales, Monmouth Junction, N. J. | Improvement in compounds for preserving wood. | 142,453 | Sept. 2, 1873 |
| H. W. Fawcett, Titusville, Pa. and Thomson McGowan, Meredith, Pa. | Improvement in preserving wood. | 123,009 | Jan. 23, 1872 |
| J. S. George, Ferndale, Wash. | Injecting apparatus. | 765,312 | July 19, 1904 |
| Jos. L. Ferrell, Philadelphia, Pa. | Method of and apparatus for fireproofing wood, etc. | 620,114 | Feb. 28, 1899 |
| Jos. L. Ferrell, Philadelphia, Pa. | Process of impregnating wood. | 694,956 | Mar. 11, 1902 |
| Jos. L. Ferrell, Philadelphia, Pa. | Process of impregnating wood with fireproofing preservatives, etc. | 695,450 | Mar. 18, 1902 |
| Jos. L. Ferrell, Philadelphia, Pa. | Fireproofed wood and method of of making same. | 695,678 | Mar. 18, 1902 |
| Jos. L. Ferrell, Philadelphia, Pa. | Fireproofing compound and method of making same. | 695,679 | Mar. 18, 1902 |
| Jos. L. Ferrell, Philadelphia, Pa. | Apparatus for impregnating wood. | 716,400 | Dec. 23, 1902 |
| Jos. L. Ferrell, Philadelphia, Pa. | Apparatus for impregnating wood. | 716,401 | Dec. 23, 1902 |
| Jos. L. Ferrell, Philadelphia, Pa. | Apparatus for impregnating wood. | 727,928 | May 12, 1903 |
| Jos. L. Ferrell, Philadelphia, Pa. | Fireproof wood, etc., and the art of making same. | 728,452 | May 19, 1903 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Jos. L. Ferrell, Philadelphia, Pa. | Process of fireproofing wood. | 767,514 | Aug. 16, 1904 |
| Lewis Feuchtwanger, New York, N. Y. | Improvement in preserving wood. | 123,467 | Feb. 6, 1872 |
| J. W. Fielder, Princeton, N. J. | Improvement in apparatus for preserving wood by the Robbins Process. | 115,946 | June 13, 1871 |
| Henry Flad, St. Louis, Mo. | Method of seasoning wood. | 231,783 | Aug. 31, 1880 |
| Henry Flad, St. Louis, Mo. | Process of preserving wood. | 231,784 | Aug. 31, 1880 |
| Henry Flad, St. Louis, Mo. | Apparatus for the treatment of timber for preserving it. | 253,361 | Feb. 7, 1882 |
| Webster Flockton, Bermondsey, Eng. | Inprovement in metallic solutions for the preservation of timber. | 130 | Feb. 16, 1837 |
| H. P. Folsom, and Howard Jones, Circleville, Ohio. | Sterilized erected pole. | 837,820 | Dec. 4, 1906 |
| Henry Page Folsom and Howard Jones, Circleville, Ohio. | Sterilizing and preserving posts and poles. | 894,619 | July 28, 1908 |
| B. S. Foreman, Morrison, Ill. | Improvement in preserving wood, railroad ties, etc. | 43,191 | June 21, 1864 |
| B. S. Foreman, | Improvement in preserving wood, railroad ties, etc. | 4,360 | May 2, 1871 |
| E. M. Fowler, New York, N. Y. | Improvement in preserving blocks of wood. | 112,136 | Feb. 28, 1871 |
| J. D. Francks, Hanover, Germany. | Process for preserving wood. | 231,419 | Aug. 24, 1880 |
| Chas. S. Friedman, Philadelphia, Pa. | Method of creosoting wood. | 693,697 | Feb. 18, 1902 |
| Wm. T. Garratt, San Francisco, Cal. and S. J. Lynch, Santa Cruz, Cal. | Improvement in protecting wooden piles. | 215,600 | May 20, 1879 |
| Louis Cathman, Washington, D. C. | Drying apparatus. | 766,340 | Aug. 2, 1904 |
| Jas. H. Gatling, Murfreesborough, N. C. | Improvement in treating the timber of old field pines. | 113,158 | Mar. 28, 1871 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| J. W. Geibel, Loysburg, Pa. | Process of removing sap, etc., from wood. | 825,819 | July 10, 1906 |
| Joseph F. Geisler, New York, N. Y. | Fireproofing and preserving wood. | 560,614 | May 19, 1896 |
| Jos. F. Geisler, New York, N. Y. | Process of fireproofing and preserving wood. | 675,826 | June 4, 1901 |
| Jos. F. Geisler, New York, N. Y. | Process of fireproofing wood. | 679,739 | Aug. 6, 1901 |
| J. S. George, Newport, Cre. | Method of preserving timber. | 533,587 | Feb. 5, 1895 |
| P. H. Gerhard, Austin, Tex. | Apparatus for treating timber. | 794,605 | July 11, 1905 |
| John Knowles and Robert Gilbert, London, Eng. | Method of preserving timber and other vegetable products. | 391 | Sept. 21, 1837 |
| C. C. & G. E. Gilman, Eldora, Iowa. | Fireproofing building materials. | 560,580 | May 19, 1896 |
| J. T. Gilmer, Pensacola, Fla. | Sap and gum extractor. | 858,380 | July 2, 1907 |
| J. L. Gilmore, Minneapolis, Minn. | Apparatus for creosoting the ends of poles. | 797,275 | Aug. 15, 1905 |
| Edw. Gold, Vancouver, Can. | Method of protecting piles. | 686,282 | Nov. 12, 1901 |
| A. J. Goodwin, New Smyrna, Fla. | Impregnating wood, etc., with copper. | 414,111 | Oct. 29, 1889 |
| Geo. Wm. Gordon, Philadelphia, Pa. | Process of preserving wood. | 751,981 | Feb. 9, 1904 |
| Aug. Gotthilf, New York, N. Y. | Improvement in the method of protecting timber from destruction by worms, dry rot or other processes of spontaneous decay. | 232 | June 14, 1837 |
| Wm. D. Grimshaw, New York, N. Y. | Improvement in processes and apparatus for preserving and curing wood. | 218,624 | Aug. 19, 1879 |
| Gustaf Grondal, Djursholm, Sweden. | Channel-furnace for treating wood. | 245,162 | Oct. 31, 1905 |
| Hugo Gronwald, Berlin, Germany. | Process of preserving cork. | 273,645 | Sept. 11, 1906 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Hugo Gronwald, Berlin, Germany. | Process of preserving cork. | 830,831 | Sept. 11, 1906 |
| Tomaso Guissani, Milan, Italy. | Process of preserving wood. | 707,224 | Aug. 19, 1902 |
| Tomaso Guissani, Milan, Italy. | Apparatus for impregnating wood. | 713,630 | Nov. 13, 1902 |
| Stuart Gwynn, New York, N. Y. | Improved process of saturating wood, cloth, paper, etc., with paraffine. | 52,788 | Feb. 20, 1866 |
| Erwin Hagen, St. Louis, Mo. | Preserving wood. | 246,762 | Sept. 6, 1881 |
| Francis Hall, Tacoma, Wash. | Method of preserving wood. | 506,493 | Oct. 10, 1893 |
| Wm. A. Hall, New York, N. Y. | Art of coloring and fireproofing wood. | 961,123 | June 14, 1910 |
| Alex, Hamar, Hungary, Austria. | Improvement in preserving wood from decay. | 48,636 | July 4, 1865 |
| Alex, Hamar, Hungary, Austria. | Improvement in preserving timber. | 51,528 | Dec. 12, 1865 |
| Louis Hanson, Wilmington, N. C. | Apparatus for preserving and creosoting wood. | 722,505 | Mar. 10, 1903 |
| Ludvig Hansen and Andrew Smith, Wilmington, N. C. | Apparatus for creosoting wood. | 316,961 | May 5, 1885 |
| Ludvig Hansen and Andrew Smith, Wilmington, N. C. | Process for preserving wood. | 317,129 | May 5, 1885 |
| Ludvig Hansen and Andrew Smith, Wilmington, N. C. | Wood-preserving apparatus. | 322,819 | July 21, 1885 |
| Thos. Hanvey, Lancaster, N. Y. | Improvement in preparing and preserving wood. | 62,956 | Mar. 19, 1867 |
| Smith T. Harding, Morrison, Ill. | Improved compound for preserving wood. | 68,069 | Aug. 27, 1867 |
| Louis Harmyer, Cincinnati, Ohio. | Improved composition for preserving wood, metal, canvas, etc. | 73,246 | Jan. 14, 1868 |
| S. E. Haskin, Avoca, N. Y. | Method of vulcanising wood. | 399,196 | Mar. 5, 1889 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| S. E. Haskin, Avoca, N. Y. | Process of and apparatus for vulcanizing wood. | 488,967 | Dec. 27, 1892 |
| Fritz Hasselmann, Rapfelburg, Germany. | Method of impregnating wood. | 580,488 | April 13, 1897 |
| Fritz Hasselmann, Munich-Nymphenburg, Ger. | Method of impregnating wood. | 626,538 | June 6, 1899 |
| Hermann Haupt, Philadelphia, Pa. | Improvement in drying, preserving, and coloring wood or other fibrous material. | 99,186 | Jan. 25, 1870 |
| Robt. T. Havens, Wilmington, Ohio. | Improved process for preparing wood for boots and shoes. | 54,339 | May 1, 1866 |
| Joshua R. Hayes, Washington, D. C. | Improvement in preserving wood. | 107,904 | Oct. 4, 1870 |
| Ira Hayford, Boston, Mass. | Improvement in the process and apparatus for treating wood. | 101,012 | Mar. 22, 1870 |
| Ira Hayford, Boston, Mass. | Improvement in processes and apparatus for treating wood. | 127,482 | June 4, 1872 |
| Ira Hayford, Boston, Mass. | Improvement in apparatus and processes for preserving wood. | 194,773 | Sept. 4, 1877 |
| Wm. Hayman, Taunton, Mass. | Improvement in compositions for preserving wood. | 110,652 | Jan. 3, 1871 |
| Theo. Wm. Heinemann, New York, N. Y. | Improved mode of purifying, seasoning, and preserving wood. | 76,757 | Apr. 14, 1868 |
| Theo. Wm. Heinemann, New York, N. Y. | Improved method of seasoning and preserving wood. | 94,204 | Aug. 17, 1869 |
| T. W. Heinemann, New York, N. Y. | Improved process and apparatus for preserving wood. | 95,474 | Oct. 5, 1869 |
| Hubert, Higgins, Cambridge, Eng. | Apparatus for impregnating and seasoning wood. | 695,152 | Mar. 11, 1902 |
| Arthur Holmes, Cortland, N. Y. | Improvement in preserving wood from decay. | 62,334 | Feb. 26, 1876 |
| Ira Holmes, Moscow, N. Y. | Improvement in compounds for preserving wood. | 124,358 | Mar. 5, 1872 |
| H. L. Houghton, Morrison, Ill. | Improved composition for hardening and preserving wood. | 65,674 | June 11, 1867 |
| Chas. Howard, New York, N. Y. | Process of and apparatus for saturating wood. | 557,271 | Mar. 31, 1896 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Chas. Howard, New York, N. Y. | Process for preserving wood. | 899,400 | Sept. 22, 1908 |
| Wm. Howe, Seattle, Wash. | Pile-protector. | 900,929 | Oct. 13, 1908 |
| Frank A. Howig, San Francisco, Cal. | Improvement in production of wooden bottle-stoppers and bungs. | 197,220 | Nov. 20, 1877 |
| Pierre Hugon, Paris, France. | Improvement in apparatus for carbonising wood. | 48,882 | July 18, 1865 |
| D. W. Hunt, San Francisco, Cal. | Improved machine for kyanising wood. | 91,848 | June 22, 1869 |
| David W. Hunt, San Francisco, Cal. | Improvement in machines for kyanising wood. | 6,848 | Jan. 11, 1876 |
| John Huntington, Cleveland, Ohio. | Improvement in devices for impregnating timber with antiseptic fluid. | 171,135 | Dec. 14, 1875 |
| John Huntington, Cleveland, Ohio. | Improvement in devices for impregnating timber with antiseptic fluids. | 171,136 | Dec. 14, 1875 |
| Warren Iddings, Warren Ohio. | Preserving and hardening wood. | 398,619 | Feb. 26, 1859 |
| B. A. Jeager, Bower's Station, Pa. | Improved compound for preserving wood. | 81,172 | Aug. 18, 1868 |
| Paul Jaeger, Esslingen, Germany. | Method of and apparatus for impregnating and dyeing wood. | 578,516 | Mar. 9, 1897 |
| B. H. Jenks, Bridesburg, Pa. | Improved process for coloring wood. | 55,110 | May 29, 1866 |
| B. H. Jenks, Bridesburg, Pa. | Improved mode of treating wood for the manufacture of carding-engines. | 55,111 | May 29, 1866 |
| B. H. Jenks, Bridesburg, Pa. | Improved process of seasoning wood. | 58,425 | Oct. 2, 1866 |
| Joseph Jones, New Orleans, La. | Improvement in preserving wood. | 118,245 | Aug. 18, 1871 |
| Thos. Jones, Calstock, Eng. | Improvement in processes for preserving wood. | 155,191 | Sept. 22, 1874 |
| Wm. H. Jones, Rochester, N. Y. | Improvement in processes of preserving wood. | 132,584 | Oct. 29, 1872 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Chas. Karmrodt and Nicholas Thilmany, Bonn, Prussia. | Improvement in preserving wood. | 132,584 | Mar. 30, 1869 |
| Carl Kleinschmidt, Seattle, Wash. | Wood-preserving compound. | 697,632 | Apr. 15, 1902 |
| Ernst Koepfer, Vienna, Austria-Hungary. | Apparatus for impregnating wood. | 910,546 | Jan. 26, 1909 |
| Franz L. Konrad, Munster, Germany. | Method of fireproofing wood. | 629,861 | Aug. 1, 1899 |
| H. E. Kreuter, Dallas, Tex. | Apparatus for treating timber, railway ties, etc. | 249,953 | Nov. 22, 1881 |
| Rudolph Kroll, Spearfish, So. Dak. | Wood preservation by means of borings in timber to permit the entrance of air. | 727,975 | May 12, 1903 |
| George Kron, Copenhagen, Denmark. | Method of producing liquid-tight joints for impregnating wood. | 256,456 | April 19, 1905 |
| Berthold Kuckuck, Wannsee near Berlin, Ger. | Apparatus for impregnating wood or other substances. | 866,487 | Sept. 17, 1907 |
| John Howard Kyan, Cheltenham, Eng. | Improved mode of preserving timber and other vegetable substances from decay. | 800 | June 23, 1838 |
| Sylvester W. Labrot, New Orleans, La. | Process of preserving wood. | 862,488 | Aug. 6, 1907 |
| Jas. Guy La Fonte, Indianapolis, Ind. | Improvement in treatment of wood for corset stays, etc. | 201,022 | Mar. 5, 1878 |
| Fred. E. Lampert, San Francisco, Cal. | Coating for piles. | 454,744 | June 23, 1891 |
| C. S. Lawrence, Plainfield, Wis. | Wood-preserving compound. | 682,363 | Sept. 10, 1901 |
| Fred. Lear, St. Louis, Mo. | Improvement in coloring and preserving wood. | 109,027 | Nov. 8, 1870 |
| Fred. Lear, St. Louis, Mo. | Improvement in preserving, coloring, and seasoning wood. | 116,969 | July 11, 1871 |
| Georg Friedrich Lebioda, Boulogne-sur-Seine, France. | Apparatus for dyeing and impregnating wood. | 609,442 | Aug. 23, 1898 |
| Georg Friedrich Lebioda, Boulogne-sur-Seine, France. | Apparatus for impregnating wood. | 644,252 | Feb. 27, 1900 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Georg Friedrich Lebioda, Boulogne-sur-Seine, France. | Apparatus for impregnating wood. | 655,788 | Aug. 14, 1900 |
| Georg Friedrich Lebioda, Boulogne-sur-Seine, France. | Apparatus for impregnating wood. | 689,317 | Dec. 17, 1901 |
| Georg Friedrich Lebioda, Boulogne-sur-Seine, France. | Process of obtaining impregnated wood. | 729,362 | May 26, 1903 |
| Chas. T. Lee, Boston, Mass. | Process of preserving wood. | 419,858 | Jan. 21, 1890 |
| Louis L. Le Franc, Bosc-le-Hard, France. | Manufacture of wooden stoppers. | 663,234 | Dec. 4, 1900 |
| Iens P. Lihme, Cleveland, Ohio. | Preserved wood and process of preparing same. | 756,173 | Mar. 29, 1904 |
| John T. Lloyd, New York, N. Y. | Vulcanising wood. | 566,591 | Aug. 25, 1896 |
| Fred. A. Lobert, National City, Cal. | Compound for preserving timber. | 546,960 | Sept. 24, 1895 |
| Rembrandt Lockwood, Brooklyn, N. Y. | Improvement in processes of treating wood. | 174,914 | Mar. 21, 1876 |
| John Thos. Logan, Texarkana, Tex. | Process of preserving wood. | 831,793 | Sept. 25, 1906 |
| J. T. Logan, Texarkana, Tex. | Apparatus for treating the butt-ends of logs. | 836,592 | Nov. 20, 1906 |
| John Loomis, Jeffersonville, Ind. | Solution for seasoning and preserving wood. | 273,861 | Mar. 13, 1883 |
| Ira Loughborough, Pittsford, N. Y. | Apparatus for saturating railroad ties. | 533,543 | Feb. 5, 1895 |
| Cuthbert B. Lowry, Lexington, Ky. | Wood impregnation. | 831,450 | Sept. 18, 1906 |
| Cuthbert B. Lowry, Lexington, Ky., Richard Bernhard, Chicago, Ill. | Means for withdrawing and condensing vapors. | 902,097 | Oct. 27, 1908 |
| M. A. Luckenbach, Denver, Col. | Process of treating wood to prevent decay. | 473,705 | Apr. 26, 1892 |
| Geo. A. Ludington Akron, Ohio. | Method of vulcanising tires in continuous lengths. | 754,078 | Mar. 8, 1904 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Gregory Lukins, Sweetwater, Ill. | Preserving wood. | 245,845 | Aug. 16, 1881 |
| Antionette Macauley, Ft. Dodge, Iowa. | Wood-preserving compound. | 778,321 | Dec. 27, 1904 |
| J. C. Mallonee, Charleston, S. C. | Process of preserving wood. | 386,999 | July 31, 1888 |
| Ernst Marmetschke, Schopfurth near Eberswalde, Ger. | Method of impregnating timber and the like. | 898,246 | Sept. 8, 1908 |
| J. C. Marshall, Oakland, Cal. | Wood-preserving compound. | 259,030 | June 6, 1882 |
| J. A. Mathieu, Detroit, Mich. | Apparatus for preserving railway ties. | 332,097 | Dec. 8, 1885 |
| H. G. McGonegal. Washington, D. C. | Improvement in apparattus for preserving wood. | 140,520 | July 1, 1873 |
| Jas. McKeon, Oakland, Cal. | Process of preserving timber. | 461,365 | Oct. 13, 1891 |
| John McLachlan, Chicago, Ill. | Process of solidifying wood. | 575,973 | Jan. 26, 1897 |
| A. R. McNair, New York, N. Y. | Improvement in preserving wood from decay and mildew. | 94,626 | Sept. 7, 1869 |
| Wm. K. Miller, Canton, Ohio. | Improvement in burial cases. | 57,545 | Aug. 28, 1866 |
| E. P. Morong, Boston, Mass. | Improvement in preserving wooden pavements. | 134,479 | Dec. 31, 1872 |
| L. D. Mott, Marshalltown, Ia. | Compound for preserving wood and metal. | 251,918 | Jan. 3, 1882 |
| H. G. Muller, San Francisco, Cal. | Preserved wood. | 236,065 | Dec. 28, 1880 |
| Peter Murray, Seattle, Wash. | Method of preserving timber. | 495,991 | Apr. 25, 1893 |
| H. C. Myers, Cleveland, Ohio. | Method of vulcanizing wood. | 537,393 | Apr. 9, 1895 |
| Robt. Newell, Philadelphia, Pa. | Improvement in compounds for coating wood and other articles to render them acid proof. | 140,530 | June 21, 1873 |
| B. R. Nickerson, San Francisco, Cal. | Improvement in preserving and hardening wood. | 107,620 | Sept. 20, 1870 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Wm. C. Jones, W. J. R. Stratford, F. B. Byrnes, and E. J. Nixon, Texarkana, Tex. | Process of saturating wood. | 216,286 | Nov. 7, 1905 |
| Patrick O'Brien, South Bend, Ind. | Improvement in processes for preparing the surface of wood-work of carriages. | 175,621 | Apr. 4, 1876 |
| John Oliver, Toronto, Can. | Improvement in preserving and drying lumber. | 142,347 | Sept. 2, 1873 |
| Geo. Palmer Littlestown, Pa. | Improvement in preserving wood. | 49,146 | Aug. 1, 1865 |
| Chas. W. Parker, Genesee Fork, Pa. | Preserving posts, etc. | 378,459 | Feb. 28, 1888 |
| Wm. D. Patten, New York, N. Y. | Fireproofing compound. | 802,311 | Oct. 17, 1905 |
| Jos. Paul, and Ira Hayford, Boston, Mass. | Improved process of treating wood to preserve, season and give it a better surface. | 95,583 | Oct. 5, 1869 |
| Chas. Payne, South Lambeth, Eng. | Improvement in processes for preserving wood. | 7,399 | May 28, 1850 |
| Wm. T. Pelton, New York, N. Y. | Improvement in portable apparatus for preserving wood. | 113,338 | Apr. 4, 1871 |
| Wm. T. Pelton, New York, N. Y. | Improvement in apparatus for seasoning and preserving wood. | 124,080 | Feb. 27, 1872 |
| Herbert Elmer Percival, Houston, Tex. | Wood-preserving compound. | 891,726 | June 23, 1908 |
| Saml. R. Percy, New York, N. Y. | Preserving wood. | 249,856 | Nov. 22, 1881 |
| Josef Pfister, Vienna, Austria-Hungary. | Method of preserving timber. | 683,792 | Oct. 1, 1901 |
| Josef Pfister, Vienna, Austria-Hungary. | Process of staining woods. | 708,069 | Sept. 2, 1903 |
| Josef Pfister, Vienna, Austria-Hungary. | Apparatus for impregnating or staining wood. | 735,019 | July 28, 1903 |
| Geo. Phillips, Key West, Fla. | Coating for wooden structures. | 414,247 | Nov. 5, 1889 |
| Geo. Phillips, Key West, Fla. | Process of preserving wood. | 414,249 | Nov. 5, 1889 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| A. M. Pierce, Brooklyn, N. Y. | Process of fireproofing wood. | 737,468 | Aug. 25, 1903 |
| Wm. Powell, Liverpool, Eng. | Vulcanised wood and process of vulcanising same. | 755,240 | Mar. 22, 1904 |
| Theo. Pridham, Petersham, New So. Wales. | Coating for timber. | 453,821 | June 9, 1891 |
| D. R. Prindle, East Bethany, N. Y. | Improved process of preserving wood and timber. | 63,300 | Mar. 26, 1867 |
| Thos. N. Prudden, San Francisco, Cal. | Method and apparatus for protecting marine wooden structures. | 855,588 | June 4, 1907 |
| A. D. Purinton, Dover, N. H. | Improved composition for setting posts, timbers, etc. | 78,691 | June 9, 1868 |
| Geo. Pustkuchen, Hoboken, N. J. | Improved apparatus for impregnating wood with tar and other materials. | 64,703 | May 14, 1867 |
| Jos. W. Putman, New Orleans, La. | Apparatus for treating wood for preserving it. | 247,947 | Oct. 4, 1881 |
| Jos. W. Putman, New Orleans, La. | Apparatus for treating timber with antiseptics. | 266,516 | Oct. 24, 1882 |
| Jos. W. Putman, New Orleans, La. | Compound for preserving timber. | 404,302 | May 28, 1889 |
| Jos. W. Putman, New Orleans, La. | Wood-preserving compound. | 405,907 | June 25, 1889 |
| Randolph. F. Radebaugh, Tacoma, Wash. | Process of and apparatus for treating wooden stopples. | 535,770 | Mar. 12, 1895 |
| Frederick Ransome, Ipswich, Great Britain. | Improvement in preserving timber. | 55,216 | May 29, 1866 |
| John M. Reid, Allegheny City, Pa. | Improvement in preserving wood. | 154,767 | Sept. 8, 1874 |
| Peter C. Reilly, Indianapolis, Ind. | Preserved wood and method of making same. | 901,557 | Oct. 20, 1908 |
| Peter C. Reilly, Indianapolis, Ind. | Preserved wood. | 899,904<br>899,905 | Sept. 29, 1908 |
| R. P. Reynolds, Walla Walla, Wash. | Timber preservative. | 792,458 | July 13, 1905 |
| H. L. Ricks, Eureka, Cal. | Method of preserving submeged timbers. | 380,820 | Apr. 10, 1888 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Saml. Ringgold, Fla. and Edw. Earle, Savannah, Ga. | Improved mode of preserving timber by boiling the same in lime-water. | 877 | Aug. 6, 1838 |
| L. S. Robbins, New York, N. Y. | Improved process for preserving wood. | 47,132 | Apr. 4, 1865 |
| L. S. Robbins, New York, N. Y. | Improved mode of preserving telegraph poles. | 89,345 | Apr. 27, 1869 |
| L. S. Robbins, New York, N. Y. | Improvement in processes for preserving wood. | 165,768 | July 20, 1875 |
| L. S. Robbins, Elizabeth, N. J. | Improvement in processes and apparatus for preserving wood or lumber. | 217,022 | July 1, 1879 |
| L. S. Robbins, New York, N. Y. | Preserving wood. | 9,512 | Dec. 21, 1880 |
| J. G. Robinson, Brooklyn, Ala. | Fence-post. | 655,638 | Aug. 7, 1900 |
| W. W. Robinson, Ripon, Wis. | Process of preserving wood. | 294,676 | Mar. 4, 1884 |
| H. N. Roge, Edouard Poret, Pierre Baffoy, and Pierre Dupre, Paris, France. | Improvement in processes of preserving wood and other vegetable matters. | 191,257 | May 29, 1877 |
| Jas. Rowe, San Francisco, Cal. | Composition for protecting piles. | 440,832 | Nov. 18, 1890 |
| Sam'l. M. Rowe, Chicago, Ill. | Door mechanism for creosoting tanks. | 908,144 | Dec. 29, 1908 |
| Karl Rucker, Zernsdorf, Ger. | Method of fireproofing wood. | 691,812 | Jan. 28, 1902 |
| Max Ruping, Charlottenburg, Ger. | Method of impregnating wood. | 707,799<br>709,799 | Sept. 23, 1902 |
| Julius Rutgers, Berlin, Germany. | Wood-impregnating compound and method of making same. | 662,310 | Nov. 20, 1900 |
| Emile Sabathe, and Louis Jourdan, Paris, France. | Improvement in impregnating substances with preservative material. | 58,036 | Sept. 11, 1866 |
| Thos. H. Sampson New Orleans, La. | Process of preserving lumber. | 403,144 | May 14, 1889 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| J. L. Samuels, San Francisco, Cal. | Improved composition for preparing and hardening wood and preserving the same. | 60,794 | Jan. 1, 1867 |
| Chr. Schallberger, Seattle, Wash. | Compound for protecting timber. | 678,201 | July 9, 1901 |
| Chr. Schallberger, Vancouver, Can. | Wood-preserving compound. | 714,521 | Nov. 25, 1902 |
| Julius Schenkel, Dortmund, Ger. | Process of impregnating wood. | 655,459 | Aug. 7, 1900 |
| Julius Schenkel, Dortmund, Ger. | Process of fireproofing wood. | 647,428 | Apr. 10, 1900 |
| P. Schmidt, | Preserving wood. | 4,560 | June 6, 1846 |
| Jos. Schneible, New York, N. Y. | Method of and apparatus for saturating corks. | 599,798 | Mar. 1, 1898 |
| Chas. A. Seely, New York, N. Y. | Improved method of impregnating wood with oleaginous and saline matters. | 69,260 | Sept. 24, 1867 |
| Jos. A. Sewall, Denver, Colo. | Process of preserving wood. | 374,208 | Dec. 6, 1887 |
| A. J. Sheldon, Buffalo, N. Y. | Improvement in preserving wood. | 106,625 | Aug. 23, 1870 |
| Morris Sherman, Chattanooga, Tenn. | Means for securing heads to boilers, cylinders, etc. | 781,371 | Jan. 31, 1905 |
| S. L. Shuffleton, Seattle, Wash. | Method of protecting wooden piles. | 676,704 | June 18, 1901 |
| J. E. Siebel, Chicago, Ill. | Improvement in depilating hides and preserving wood. | 116,638 | July 4, 1871 |
| H. V. Simpson, London, Eng. | Fireproofing wood. | 646,101 | Mar. 27, 1900 |
| H. V. Simpson, London, Eng. | Process of fireproofing wood. | 668,227 | Feb. 19, 1901 |
| Archibald J. Sinclair, Chicago, Ill. | Process of coating porous material with asphalt. | 893,391 | July 14, 1908 |
| Smith A. Skinner, Hoosick Falls, N. Y. | Cordage and twine to be used in binding sheaves of grain. | 255,040 | Mar. 14, 1882 |
| Bat Smith Spanish Camp, Tex. | Composition for preserving wood. | 244,327 | July 12, 1881 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Geo. B. Smith, Philadelphia, Pa | Improvement in apparatus for preserving wood. | 160,846 | Mar. 16, 1875 |
| Geo. B. Smith, Philadelphia, Pa. | Improvement in wooden shingles made fire-proof. | 199,001 | Jan. 8, 1878 |
| W. B. Smith, La Fayette, Ill. | Improved apparatus for saturating timber. | 62,295 | Feb. 19, 1867 |
| W. H. Smith, Steubenville, Ohio. | Improvement in apparatus for injecting preservative liquids into wood. | 111,784 | Feb. 14, 1871 |
| W. L. Smith, New York, N. Y. | Apparatus for impregnating wood. | 711,080 | Oct. 14, 1902 |
| P. S. Smout, Everett, Wash. | Composition for preserving piles and timber. | 806,591 | Dec. 5, 1905 |
| Edw. Spaulding, Brooklyn, N. Y. | Improved process for treating wood. | 77,777 | May 12, 1868 |
| S. F. Spaulding, Jerico, Conn. | Improvement in preparing veneers for butter-boxes. | 164,945 | June 29, 1875 |
| Geo. Speis, Dutch Kills, N. Y. | Preserving wood. | 387,375 | Aug. 7, 1888 |
| Chas. F. Spicker, New York, N. Y. | Improvement in coloring and hardening wood. | 3,635 | June 24, 1844 |
| I. B. Sprague, Everett, Wash. | Process of preserving wood. | 694,212 | Feb. 25, 1902 |
| Jas. D. Stanley, Eastover, S. C. | Device for charring surface of timber. | 361,095 | Apr. 12, 1887 |
| Jas. D. Stanley, Wilmington, N. C. | Apparatus for charring timber. | 282,395 | July 31, 1883 |
| Jas. D. Stanley, Eastover, S. C. | Device for charring logs. | 361,193 | Apr. 12, 1887 |
| Chas. W. Stanton, Mobile, Ala. | Apparatus for steaming wood. | 735,608 | Aug. 4, 1903 |
| Adolphe Ste. Marie and Alfred Hoffman, Lyons, France. | Process of seasoning wood. | 675,500 | June 4, 1901 |
| Jas. C. Stead, Jersey City, N. J. | Improvement in apparatus for preserving wood. | 148,630 | Mar. 17, 1874 |
| L. M. Stern and Edw. M. Kempner, Buffalo, N. Y. | Apparatus for impregnating wood. | 662,104 | Nov. 20, 1900 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| F. A. Stevens, Chicago, Ill. | Improvement in apparatus for preserving wood. | 102,725 | May 3, 1870 |
| Chas. Stollberg, Toledo, Ohio. | Sheet-metal sap receptacle or vessel. | 857,846 | June 25, 1907 |
| Richard Sutphen, Freehold, N. J. | Improvement in wood-preserving compositions. | 120,009 | Oct. 17, 1871 |
| Geo. W. Swan, San Francisco, Cal. | Improvement in the processes for softening and toughening blocks of wood. | 142,298 | Aug. 26, 1873 |
| Wm. Taggart, San Francisco, Cal. | Preserving piles. | 261,045 | July 18, 1882 |
| A. H. Tait, Jersey City, N. J. | Improvement in preserving wood. | 115,784 | June 6, 1871 |
| Rudolf Tancsos, Vienna, Austria-Hungary. | Fireproofing wood. | 329,973 | Nov. 10, 1885 |
| Chas. Taylor, R. I. Murchison, and Geo. Sharpe, Melbourne, Victoria. | Composition for preserving timber. | 391,209 | Oct. 16, 1888 |
| J. H. Taylor, New York, N. Y. | Improved process of preventing decay in wood. | 70,761 | Nov. 12, 1867 |
| Wm. B. Taylor, Winterpark, Fla. | Composition for preserving wood. | 759,938 | May 17, 1904 |
| L. N. Teachman, Lincoln, Nebr. | Wood-preserving composition. | 277,810 | May 15, 1883 |
| Horace Thayer, Warsaw, N. Y. | Treating wood for the manufacture of boxes, cases, etc. | 45,537 | Dec. 20, 1864 |
| Waldemar Thilmany, Cleveland, Ohio. | Improvement in apparatus for impregnating timber with antiseptics. | 177,770 | May 23, 1876 |
| Waldemar Thilmany, Cleveland, Ohio. | Improvement in processes for preserving timber. | 202,678 | Apr. 23, 1878 |
| Nathan H. Thomas, New Orleans, La. | Improvement in processes for preserving wood. | 113,706 | Apr. 11, 1871 |
| A. B. Tripler, New Orleans, La. | Improvement in preserving wood. | 104,916 | June 28, 1870 |
| A. B. Tripler, New Crleans, La. | Improvement in preserving wood for railroad ties, etc. | 104,917 | June 28, 1870 |
| A. B. Tripler, Philadelphia, Pa. | Improvement in processes for preserving wooden pavements from rot. | 126,592 | May 7, 1872 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| A. B. Tripler, New York, N. Y. | Improvement in processes for staining wood. | 207,630 | Sept. 3, 1878 |
| A. B. Tripler, New York, N. Y. | Improvement in the art of preserving wood. | 208,649 | Oct. 1, 1878 |
| Abel D. Tyler, Worcester, Mass. | Impregnating wood. | 553,547 | Jan. 28, 1896 |
| Geo. S. Valentine, Brooklyn, N. Y. | Process of and apparatus for preserving wood by impregnation to given heights. | 285,087 | Sept. 18, 1883 |
| Rose L. Valleen, Seattle, Wash. | Wood-preserving compound. | 579,101 | Mar. 16, 1897 |
| G. A. Vivien and Paul C. Vivien, Honfleur, France. | Improvement in compositions for preserving wood, coating ships' bottoms, etc. | 123,801 | ? |
| J. G. Voorhees, Aqueduct Mills, N. J. | Improvement in preserving wood. | 121,141 | Nov. 21, 1871 |
| Martin Voorhees, Princeton, and G. W. N. Custis, Camden, N. J. | Improved process and apparatus for seasoning and impregnating wood with preservative material. | 87,226 | Feb. 23, 1869 |
| John F. Walter, Jr., Brooklyn, N. Y. | Process of drying and seasoning lumber. | 287,351 | Oct. 23, 1883 |
| Fred J. Warren, Newton, Mass. | Wooden block pavement. | 794,758 | July 18, 1905 |
| Chas. G. Waterbury, New York, N. Y. | Improvement in processes for hardening and preserving wood. | 124,402 | Mar. 5, 1872 |
| Ezra Webb, New York, N. Y. | Improvement in preserving wood. | 108,659 | Oct. 25, 1870 |
| Peter Welch, St. Louis, Mo. | Improvement in preserving wood. | 129,503 | July 16, 1872 |
| Wm. Wellhouse, & Erwin Hagen, St. Louis, Mo. | Improvement in preserving wood. | 216,589 | June 17, 1879 |
| Pelag Werni, Philadelphia, Pa. | Improvement in compounds for preserving wood. | 164,786 | June 22, 1875 |
| S. P. Wheeler, Bridgeport, Conn. | Improvement in the manufacture of articles of compressed wood. | 101,552 | Apr. 5, 1870 |
| S. P. Wheeler, Bridgeport, Conn. | Improved process of treating wood. | 101,553 | Apr. 5, 1870 |

**List of U. S. Patents on Wood Preservation.**—*Continued*

| Name and address of inventor | Title of patent | No. of patent | Date issued |
|---|---|---|---|
| Thos. B. White, Warsaw, Mo. | Post-protector. | 868,953 | Oct. 22, 1907 |
| Sidney S. Williams, Providence, R. I. | Apparatus for use in treating wood. | 904,589 | Nov. 24, 1908 |
| Sigmund Willner, London, Eng. | Apparatus for impregnating wood. | 620,627 | Mar. 7, 1899 |
| Sigmund Willner, London, Eng. | Apparatus for impregnating wood. | 676,060 | June 11, 1901 |
| Sigmund Willner, New York, N. Y. | Apparatus for impregnating wood. | 771,689 | Oct. 4, 1904 |
| Sigmund Willner, Memphis, Tenn. | Apparatus for forcing fluids into wood. | 807,411 | Dec. 12, 1905 |
| Sigmund Willner, Chicago, Ill. | Apparatus for injecting chemicals into logs. | 896,785 | Aug. 25, 1908 |
| Jas. P. Witherow, Pittsburg, Pa. | Process of and apparatus for vulcanizing wood. | 446,501 | Feb. 17, 1891 |
| Jas. P. Witherow, Pittsburg, Pa. | Apparatus for vulcanizing wood. | 446,500 | Feb. 17, 1891 |
| Jas. H. Young, New, York, N. Y. | Apparatus for impregnating wood. | 329,799 | Nov. 3, 1885 |
| Wm. Youngblood, Jamaica, N. Y. | Method of preserving wood. | 398,366 | Feb. 19, 1889 |

## METHOD OF ANALYZING ZINC CHLORIDE[1]

*Sampling.*—A fair average sample must be taken from one out of every ten drums. Quickly transfer the sample to a clean, dry. salt-mouthed bottle, stopper, hermetically seal and send to the laboratory for test. The sample should be marked with a number or other device, corresponding to the drum or lot from which it was taken.

*Insoluble Basic Zinc Chloride.*—Pulverize about 10 grams of the fused zinc chloride by crushing between filter papers, and quickly transfer to a weighing bottle. This operation must be performed quickly, owing to the deliquescent nature of the substance. Weigh the bottle plus the sample, transfer the sample to 500 c.c. of water in a beaker, and weigh the bottle again; the

[1] From the Proceedings of the American Wood Preservers' Association.

weight of the sample is thus obtained by difference. Cover the beaker and allow the solution to stand for 12 hours.

Filter through a weighed Gooch crucible into a liter flask. Wash the residue with cold water until it is free from chlorides. Dry the basic zinc chloride at 100° C. for about 12 hours and weigh.

Dilute the filtrate to 1000 c.c. and mix thoroughly.

*Ferric Chloride.*—Take 100 c.c. of the solution, boil, and precipitate the iron with ammonium hydroxide. Boil off the excess of ammonia, filter and reject the filtrate. Dissolve the precipitate off the paper with hot dilute hydrochloric acid, and reprecipitate with ammonium hydroxide. Filter through the original filter paper. Wash the ferric hydroxide 5 to 6 times with hot water, ignite and weigh as $Fe_2O_3$.

Factor for metallic iron, 7.

Factor for ferric chloride, 1.0156.

*Soluble Zinc.*—Take 50 c.c. of the original solution, and add a concentrated solution of sodium carbonate, until the solution is slightly alkaline. Zinc is precipitated as basic carbonate. Boil for 15 minutes. Decant through a weighed Gooch crucible and wash by decantation three or four times. Ignite at a high temperature and weigh as ZnO. Subtract the percentage of ferric oxide found above.

Factor foı metallic zinc, 0.8034.

Factor for zinc chloride, 1.7644.

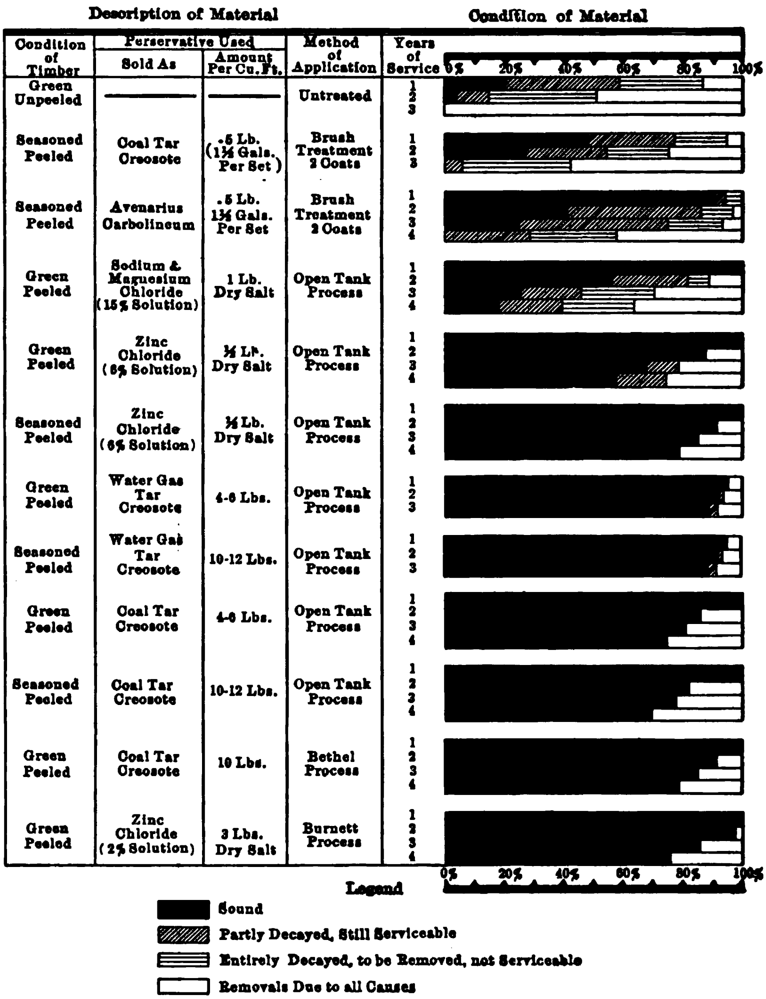
*Free Acid.*—Dissolve 10 grams of the fused chloride in 100 c.c. of distilled water, and test with methyl orange. If free acid is present, which is rarely the case, determine by titration with standard alkali. Factor, chlorine from hydrochloric acid, 0.973.

*Total Soluble Chlorine.*—Titrate 25 c.c. of the solution with standard silver nitrate, using potassium chromate as indicator. Subtract the amount of chlorine equivalent to the free hydrochloric acid present, if any, and also the chlorine combined as ferric chloride, and calculate the remainder to zinc chloride, by using the factor 2.04. The amount of zinc chloride thus obtained should check with that found from soluble zinc.

## RECORDS ON THE LIFE OF TIMBERS

**Mine Timbers.**—The U. S. Forest Service treated a large number of mine timbers according to various methods and placed

them in the coal mines of the Philadelphia and Reading Coal and Iron Company at Pottsville, Pa. Inspections were made



| Description of Material | | | | Condition of Material |
|---|---|---|---|---|
| Condition of Timber | Preservative Used: Sold As | Preservative Used: Amount Per Cu. Ft. | Method of Application | Years of Service |
| Green Unpeeled | ———— | ———— | Untreated | 1 2 3 |
| Seasoned Peeled | Coal Tar Creosote | .5 Lb. (1¼ Gals. Per Set) | Brush Treatment 2 Coats | 1 2 3 |
| Seasoned Peeled | Avenarius Carbolineum | .5 Lb. 1¼ Gals. Per Set | Brush Treatment 2 Coats | 1 2 3 4 |
| Green Peeled | Sodium & Magnesium Chloride (15% Solution) | 1 Lb. Dry Salt | Open Tank Process | 1 2 3 4 |
| Green Peeled | Zinc Chloride (6% Solution) | ½ Lb. Dry Salt | Open Tank Process | 1 2 3 4 |
| Seasoned Peeled | Zinc Chloride (6% Solution) | ½ Lb. Dry Salt | Open Tank Process | 1 2 3 4 |
| Green Peeled | Water Gas Tar Creosote | 4-6 Lbs. | Open Tank Process | 1 2 3 |
| Seasoned Peeled | Water Gas Tar Creosote | 10-12 Lbs. | Open Tank Process | 1 2 3 |
| Green Peeled | Coal Tar Creosote | 4-6 Lbs. | Open Tank Process | 1 2 3 4 |
| Seasoned Peeled | Coal Tar Creosote | 10-12 Lbs. | Open Tank Process | 1 2 3 4 |
| Green Peeled | Coal Tar Creosote | 10 Lbs. | Bethel Process | 1 2 3 4 |
| Green Peeled | Zinc Chloride (2% Solution) | 3 Lbs. Dry Salt | Burnett Process | 1 2 3 4 |



FIG. 30.—Comparative condition of treated and untreated loblolly pine gangway sets placed in the mines of the Philadelphia and Reading Coal and Iron Co.

each year for 4 years with the results graphically shown in Fig. 30.[1]

**Paving Blocks.**—In January, 1910, the American Association

[1] Bulletin 107, U. S. Forest Service.

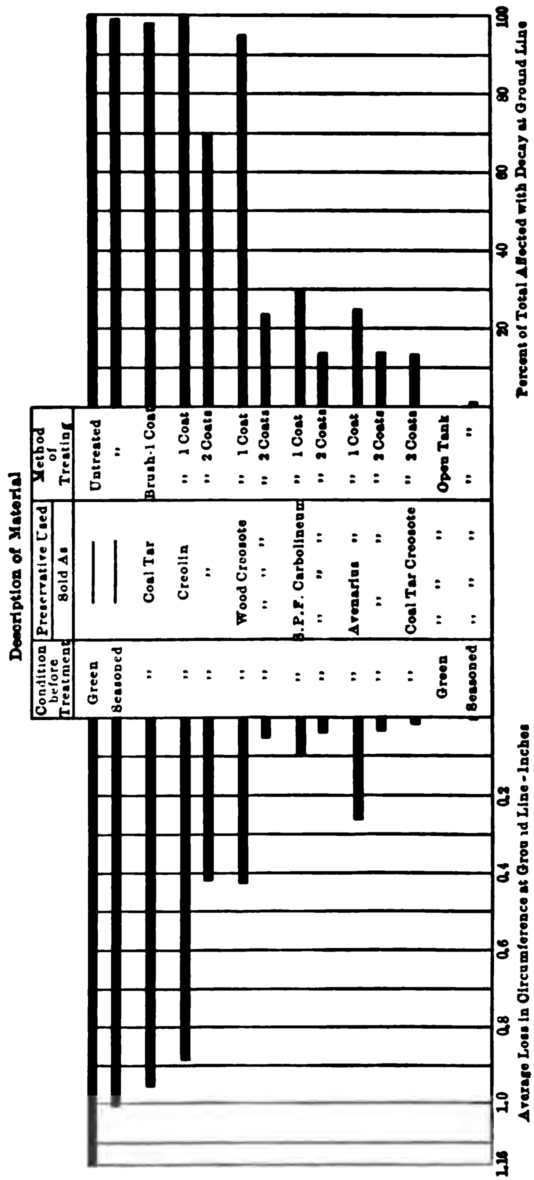



FIG. 31.—Condition of experimental poles in the Warren-Buffalo line 5 years after placement.

of Creosoted Wood Blocks Paving Manufacturers sent inquiries to various American cities to learn their experiences with wood-block paving. The replies are summarized in Table 41.

TABLE 41.—EXPERIENCE OF SOME CITIES WITH WOOD-BLOCK PAVING

| City | Years of service at last inspection. | Condition | Authority |
|---|---|---|---|
| Brooklyn............ | 7 | Good | J. C. Sheridan |
| New Orleans......... | 31 | Blocks good | R. E. Slade |
| Minneapolis.......... | 8 | No repairs | E. R. Dutton |
| St. Louis............. | 7 | Excellent | J. C. Travilla |
| Duluth.............. | 5 | No repairs | T. F. McGilvray |
| Des Moines.......... | 4 | No repairs | J. MacVicar |
| Toledo............... | 9 | No repairs | G. W. Touson |
| Detroit.............. | 5 | No repairs | R. H. McCormick |
| Grand Rapids, Mich... | 9 | Excellent | L. W. Anderson |

**Poles.**—About 1000 chestnut poles treated in various ways were set by the U. S. Forest Service in 1905 in cooperation with the American Telephone and Telegraph Company in Pennsylvania. The results after 5 years of service are shown in Fig. 31.[1]

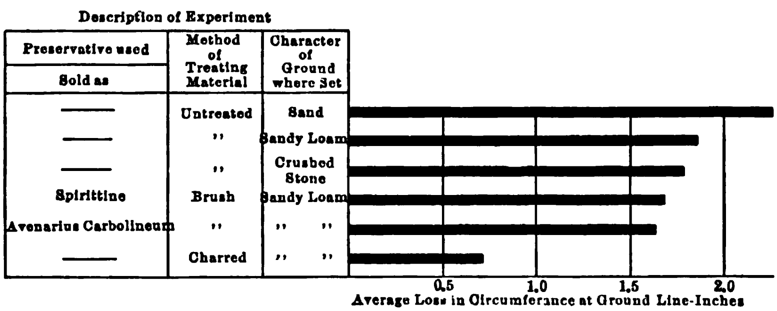



FIG. 32.—Condition of experimental poles in the Poughkeepsie-Newton Square line 8 years after placement.

A similar line was set up by the U. S. Forest Service in New Jersey in 1902. All the poles were chestnut. The results after 8 years of service are shown in Fig. 32.[2]

The German government has kept record on the life of its poles when treated by various processes, these records extending over a period of about 50 years. The general results to date are shown in Table 42.[3]

[1] Circular 198, U. S. Forest Service.
[2] Circular 198, U. S. Forest Service.
[3] Archiv für Post und Telegraphie.

TABLE 42.—AVERAGE LIFE OF DIFFERENT KINDS OF POLES TREATED WITH

| Copper sulphate | | Zinc chloride | | Dead oil of coal tar | | Corrosive sublimate | | Not treated | |
|---|---|---|---|---|---|---|---|---|---|
| Removed on account of decay poles | Total life in pole years | Removed on account of decay poles | Total life in pole years | Removed on account of decay poles | Total life of pole years | Removed on account of decay poles | Total life of pole years | Removed on account of decay poles | Total life of pole years |
| 77,606 | 750,693 | 124,300 | 1,223,497 | 30,009 | 320,597 | 11,084 | 102,012 | 5,708 | 47,528 |
| 585,463 | 6,653,334 | 48,522 | 764,528 | 53,621 | 952,801 | 102,493 | 1,346,096 | 71,105 | 535,288 |
| | 386,675 | | 76,740 | | 446,295 | | 111,184 | | 6,600 |
| 663,069 | 7,790,702 | 172,822 | 2,064,765 | 83,630 | 1,719,693 | 113,577 | 1,559,292 | 76,813 | 589,416 |
| | 11.7 years | | 11.9 years | | 20.6 years | | 13.7 years | | 7.7 years |

**Cross Ties.**—The reported life of cross-ties in service is given in Table 43, which is taken from Bulletin 118 of the U. S. Forest Service.

TABLE 43.—REPORTED LIFE OF TIES IN SERVICE

| Species | Laid by | How treated | Life |
|---|---|---|---|
| | | | *Years* |
| White oaks.... | Duluth & Iron Range Ry. Co. | Untreated | 8 to 9 |
| Spruce........ | Union Ry. Co. (horse)...... | Burnettized | 8 to 20 |
| Pine (probably western yellow, longleaf, and piñon pines). | A., T. & S. F. Ry. Co........ | ......do..... | 10½ to 15 |
| | T. & N. O. Ry. Co.......... | ......do..... | 10 to 11 |
| | H. & T. C. Ry. Co.......... | Creosoted | 19 |
| Baltic pine.... | English railroads.......... | ......do..... | 8 to 18 |
| Hemlock...... | C. R. R. of N. J........... | ......do..... | 15½ |
| | C., R. I. & P. Ry. Co. ...... | Wellhouse | 10 to 15 |
| | Duluth & Iron Range Ry.Co. | Burnettized | 8 to 10 |
| Tamarack..... | .....do.................. | ......do..... | 9⅕ |
| | Pittsburg, Ft. Wayne & Chicago Ry. Co. | Wellhouse | 8.84 |
| Beech........ | French, German, and Austrian railroads | Untreated | 4 to 5 |
| | | Burnettized | 10 to 12 |
| | | Creosoted | 18 to 30 |
| Maple........ | C. R. R. of N. J. .......... | Burnettized | 15+ |
| | German railroads .......... | ......do..... | 16 |
| Red oaks...... | Wabash R. R............. | ......do..... | 5 to 6 |
| | French and German railroads | Creosoted | 19 to 25 |

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